ENGINEERING

An Illustrated Weekly Journal

35 & 36 BEDFORD STREET, STRAND, LONDON, W.C.2 - - TELEPHONE: TEMPLE BAR 3663

Vol. 184 No. 4784 *LONDON, FRIDAY, NOVEMBER* 15, 1957 PRICE 2s.

ASSEMBLING PUMP ROTORS

Numbers photograph for ENGINEERING

NOVEMBER 15, 1957 VOL. 184 PAGES 609–640

ENGINEERING

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Published every Friday by Engineering Limited, 35 & 36 Bedford-street, London, W.C.2.
TELEPHONE: *Temple Bar* 3663. TELEGRAPHIC ADDRESS: *Engineering Lesquare London.*

Subscription Rates: 12 months, Inland and Abroad £5 10s., Canada £5 5s.; 3 months, 27s. 6d. all countries. Single copies, 2s. 7d., post free.

SAVING GRACE

It may seem an odd remark for an Englishman to make, but the last few weeks have impressed on us as never before the advantage we have in speaking English: we can communicate with the Americans. It would be fairer to our traditions to say that, fortunately, the Americans speak English, but whichever way we express the same idea the paramount fact, which has a profound influence on contemporary affairs, is that the Anglo-American alliance is flexible and can be modified at relatively short notice. It is due for some extensive modifications in the coming months.

Even in the past two weeks there has been a marked change. At that time we expressed disappointment, in a leading article, that "the Eisenhower-Macmillan talks were principally on military matters to the exclusion of the economic and commercial possibilities of Anglo-American co-operation." The surge of public discussion has since come round to that view—that Russia's *sputniks* have commercial as well as military significance. Is it possible to look ahead again, and visualise the climate of hopes and fears, intentions and frustrations, that will prevail in the near future? If we are to attempt that exercise of imagination we must look to the impressionable nations of the world—those which are riding on the crest of the wave of nationalism and whose leaders are torn between the prospect of catching up with the industrial nations and the uneasy feeling that they are already hopelessly handicapped in the race.

If the Americans and ourselves have had to make a drastic revision of Russian capabilities, how much more must the impressionable nations be startled? They will now be more inclined to look to the other side of the Iron Curtain for a lead in industrialisation—unless the West succeeds in giving adequate re-assurance that, in spite of a temporary and unexpected setback, we have the greater resources, beyond the purely material. To do that effectively we must be clear-headed about our criticisms of Russian methods. The outright denunciation of their way of life, which is the characteristic American attitude, will no longer carry much weight. And if the present Wall Street signs grow to something more ominous, the Communists will have yet another—to them—trump card to play in the game of world power.

The impressionable nations will inevitably look to the U.S.S.R., as a small boy looks to his hero, not only for advice and help but also for bolstering their own hopes of achieving industrial parity. We and the Americans must realise, too, that in spite of the fact that Russia was not entirely primitive even before the revolution forty years ago, they have shown what enormous strides a single-minded nation can take. English people who know India, for example, still say that such a country can never catch us up in industrialisation. We are not so sure now. The Indians themselves will certainly be revising their views, in their own favour, and will thereby give their people a fillip which can generate a new will to succeed in that great nation.

As we go to press the talk is of lack of co-operation between the American services, and between Britain and the United States. Professor Oppenheimer has rightly deplored the way in which our two countries allowed the war-time alliance to fade away. Mr. Woodrow Wyatt, sampling American opinion in New York, finds that folk there are now remembering that many of the inventions and developments which they have always thought of as American did in fact originate in Britain. In the same television programme in which these two appeared, Mr. Finletter—the man who headed a fast-working committee to plan the American aircraft industry after the war—pointed out that although greater co-operation is undoubtedly needed, it must not be thought that it will work miracles; there can never be complete exchange of secrets and of new developments in the embryonic stage.

There are three empirical formulae in the mechanics of Anglo-American team work at the present time. The first should tell us what Britain can do most effectively in relation to the American effort. Past history shows that we have generally excelled in research rather than in large-scale production. It is doubtful whether this view is now as true as it used to be. But it at least raises the issue. In the coming months the urgent need is for our representatives to thrash out this question to our mutual benefit. The second should tell us whether the pattern of Government departments which we, and the Americans, have inherited is appropriate to modern conditions. The appointment of Dr. James Killian as President Eisenhower's "co-ordinator in the whole field of science and engineering" has been questioned in the United States; we might equally question parts of our own State organisation. The final, and perhaps the most enduring equation is neither military nor commercial; it is humanistic, even spiritual. The Russians have got where they have because their organisation is out-and-out materialism. In spite of our obvious failings, in spite of our own brand of materialism, and even though some of the impressionable nations may call us hypocrites, the West still possesses some saving grace.

Cover Picture. *Borehole pumps have to operate fully submerged for long periods; consequently they must be accurately made and assembled. Increases of pressure head are met by additional stages—in the picture the sixth stage is being checked for alignment.*

* * *

Plain Words

Any man asked to give advice on choosing a career will seldom recommend his own. "It's a tough life, son, 24 hours a day, and no perks" is the usual answer. Thus journalists will tell you that half their life is spent waiting in the rain; actors, waiting in the wings of provincial theatres (or simply resting); salesmen, waiting on doorsteps; advertising men, waiting for lucrative accounts; and television raconteurs, waiting for panel recognition. Yet these are the very careers that many young people yearn for—apart from the would-be skiffle millionaires. They seem to represent rich and varied lives, full of fascinating contacts, travel and adventure. How are the young to be disillusioned? How can they be shown that work is work, however well disguised?

A fresh approach to *Choosing a Career* is adopted in a well devised and presented booklet published by the National Union of Students. Under the title "Do You Want to Be a Journalist?" a Fleet Street reporter gives the low down on the wretchedness of his condition. The article is surrounded in current Fleet Street style with advertisements tied to the subject of the article; but in this case the advertisements offer welcome alternatives to the misery described.

But few will be convinced. Those who long to be involved in world events will still believe themselves to be dedicated writers; only when at last they are taking notes at a Press conference, where some quiet, confident scientist—now the head of an atomic energy establishment—or some accountant or engineer is explaining how the job was done, will they realise that the journalist is always a bystander, never a protagonist.

To-day, there is an excitement in events; the longing to be a part of them is illustrated by the many thousand volunteers prepared to risk their lives on a first flight to the moon. But the men who go will almost certainly be specialists, men who have devoted their whole attention to a task, jacks of a single trade with a history of routine.

The desire to be uncommitted, to be free and independent, makes industry seem an ogre to many young people. "I couldn't bear industry" is a common enough expression among undergraduates. The same impulse leads others to choose sales promotion rather than production, once industry has claimed them.

How can the truth be told? The test pilot who tells his nephew that he spends his time just watching a lot of dials is unlikely to be believed. It is as difficult to explain that industry is full of rich opportunities. "Don't put your daughter on the stage, Mrs. Worthington" continues to be sound advice. The substance can be far more satisfying than the shadow.

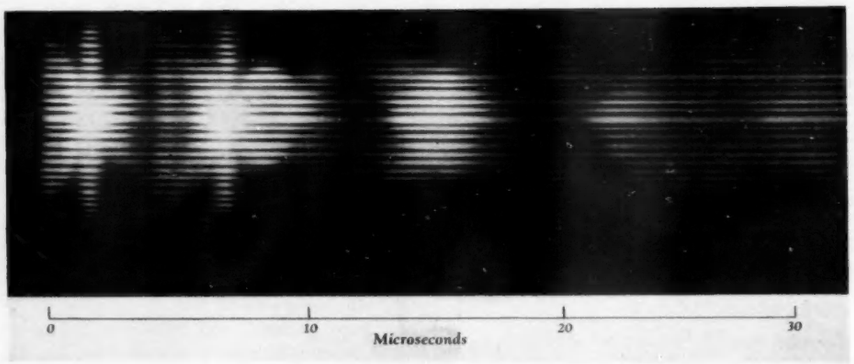

Fig. 1 Streak photograph of 15,000 ampere discharge in low-pressure krypton, showing contracting and expanding discharge. The tube diameter is 1¼ in.

The prospect that seawater may one day provide the world's main source of energy has created wide interest in nuclear fusion. Fusion reactions between light nuclei have long been recognised as possible, and various approaches have been proposed with the object of producing power in this way. Probably the best-known approach is that described as thermonuclear fusion, which is the subject of this article. Dr. A. A. Ware places thermonuclear fusion in its scientific and historical context, underlining its significance and referring to the principal contributions made by workers in this field. Dr. Ware, who took part in the first thermonuclear studies undertaken in this country—at Imperial College under the direction of Sir George Thomson—is now in charge of thermonuclear work at the Research Laboratory of Associated Electrical Industries Limited, where the research begun at Imperial College has been continued.

CONTROLLED

It is now almost thirty years since thermonuclear reactions were first postulated by Atkinson and Houtermans[1] and more than twenty since there were well established theories of how these reactions provided the energy of the sun and the stars. The knowledge of this potential source of energy therefore preceded that of uranium fission by about ten years. It might seem surprising that it was not until after the uranium reactor and the atomic bomb had been developed that work was commenced on trying to produce terrestrial thermonuclear reactions. The reason is the extremely high temperatures required to produce such reactions. These temperatures are of the order 10^8 deg. C. and are 10^4 times greater than those which any known material can stand without vaporising, and most scientists before the war ruled out the possibility of ever achieving such temperatures on the earth. P. C. Thonemann, in Australia, was one of the few scientists who gave the matter any serious thought in those days.

When the first atom bomb was exploded, the temperatures required for a thermonuclear reaction were achieved on the earth for the first time and scientists were quick to realise that here was a detonator for a thermonuclear bomb. Such a bomb now became a possibility; but, of course, many problems had to be solved and years of expensive research were needed before hydrogen bombs were successfully exploded. In the case of controlled thermonuclear reactions, the scientists involved can look for no corresponding help from the controlled uranium reaction, since the temperatures in a fission reactor are, at most, only a few hundred degrees. They must produce the high temperatures by some other means.

The first research in this country on the production of such reactions was started in 1946 by Sir George Thomson, who was then Professor of Physics at Imperial College, London University. The calculations he carried out with the aid of Professor Blackman showed that if a gas at the required high temperatures could be contained, the energy lost by radiation would not be excessive and a useful amount of power would be generated. The problem of a material wall to contain the hot gas could be overcome, since all particles in such a hot gas would be charged and could therefore be confined by electromagnetic fields. Sir George suggested the pinch effect in a toroidal gas discharge as a possible containing-field configuration. These conclusions led Sir George to institute experimental work in the beginning of the following year by starting S. W. Cousins and the author on small experimental projects.

Independently, Dr. Thonemann, who had moved to the Clarendon Laboratory, Oxford, after the war, had been studying the hydrogen fusion reactions, these being the ones most likely for any terrestrial thermonuclear reactions. Dr. Thonemann had arrived at similar conclusions to Sir George Thomson on the feasibility of producing such reactions and a start was made on studying the pinch effect in 1948. In this way, the two groups interested in this type of research in this country came into being. The work was not secret in those days, but completely open, some of it having been published [2, 3, 4]. In fact, the few involved had a struggle persuading their colleagues to take their attempts to get such temperatures seriously.

In 1950, the Government decided to make the work secret and, owing to the undesirability of carrying out secret research in university laboratories, the two groups were moved in 1951. The work at Oxford transferred to the Atomic Energy Research Establishment at Harwell and Sir George asked Dr. T. E. Allibone, Director of the Research Laboratory, Associated Electrical Industries, to take over the Imperial College work. The group at Harwell is headed by Dr. Thonemann and is part of the General Physics Division under Mr. D. W. Fry. At Aldermaston the group is led by the author and is part of the Nuclear Physics Section headed by Mr. D. R. Chick. Although severed from his team, Sir George continued to take an active interest in the work and has played a major part in directing the A.E.I. team. Most of the work at A.E.I. is done under contract to the U.K. Atomic Energy Authority and the two groups have worked in close liaison.

That such work was in progress was first officially acknowledged by Sir John Cockcroft at the Geneva Conference on atomic energy in 1955, but no official announcement has yet been made about the nature or scale of the work being done or the progress made, although recently five theoretical papers and one short experimental note were published.[5] In this review, therefore, it is possible to give only a broad outline of the general type of approach which is being followed and the major problems which are involved.

In 1955 the Atomic Weapons Research

THERMONUCLEAR REACTIONS

By A. A. Ware, B.SC., A.R.C.S., PH.D., D.I.C.

Establishment, who, of course, have a keen interest in hydrogen fusion reactions in connection with the hydrogen bomb, began research on controlled reactions. This establishment is now a third centre contributing to the country's research programme on this project.[6]

As far as other countries are concerned, it is now well known that work on producing such controlled reactions is being done on a substantial scale in both America and Russia. It was at the same Geneva Conference that Mr. Strauss, Chairman of the United States Atomic Energy Commission, announced that the United States had been doing active research in this field since 1951, and later in the year he listed the centres of research and senior scientists involved. Since then a very good review paper has been published by Dr. R. F. Post,[7] who is one of the project leaders in the United States. Although this does not describe how they are tackling the various problems involved, it gives a very clear account of what these problems are and the physics involved. Many unofficial reports had appeared in the Press and scientific literature on the subject, but this was the first review of the problems by a scientist actually participating in the field. Professor Lyman Spitzer,[8] another project leader in the United States, has published a book on the physics of high-temperature gases which is used considerably by scientists on both sides of the Atlantic.

One of the points of agreement on atomic energy signed last year between the United Kingdom and the United States has been that the scientists of these two countries are now exchanging full information on their controlled thermonuclear projects.

Russia made no announcement at Geneva, but in 1956 when Mr. Bulganin and Mr. Khrushchev visited this country, Academician I. V. Kurchatov, who accompanied them, gave a lecture at the Atomic Energy Research Establishment at Harwell in which he described a series of experiments aimed at producing controlled thermonuclear reactions.[9] Constricted discharges were produced similar to those studied by Cousins and Ware at Imperial College, but in straight tubes and at much higher currents. It was an historic announcement because a hydrogen fusion reaction had been produced in these discharges, but unfortunately measurements had indicated that the cause of the reaction was not a high temperature but an unusual accelerating mechanism acting on the ions in the discharge. (It will be explained below why high temperatures are the necessary mechanism if a fusion reaction is to produce useful power.) This work therefore did not achieve the goal aimed at, but it brought to light further interesting characteristics of high-current discharges which add to their list of complicated hydromagnetic properties. Kurchatov's lecture has been reviewed by Dr. Thonemann.[10]

At the recent International Conference on Ionised Gases in Venice (June, 1957) some further theoretical and experimental papers were read by United States and British scientists. The most significant information released was the theory of a method of stabilising the pinched discharge (M. Rosenbluth, United States, and R. Tayler, United Kingdom.) Papers on this subject were also delivered by physicists from Germany, France and Sweden, showing the increasing interest in this field.

Fission and Fusion Reactions

The nucleus of any atom is made up of a number of protons and neutrons which are held together by strong attractive forces. The number of protons in an atom is equal to the Z number in the periodic table of the particular element. The number of neutrons can vary for a given element, but is approximately equal to the number of protons. An important property of the forces holding the particles together is that they vary in strength with the number of particles present in the nucleus and are a maximum for elements about a quarter of the way up the periodic table (Z = 24). This means that if one can imagine building up a nucleus from protons and neutrons which are originally separated, more energy will be gained per particle from the work done by the attractive forces for elements near Z = 24 than for either lighter or heavier elements. This energy is known as the binding energy. It is because of the maximum in the binding energy that there are two types of nuclear reactions which yield energy. One type involves a heavy nucleus breaking up into lighter nuclei, the other the building up of light nuclei, in both cases nuclei nearer Z = 24 being formed. These reactions are called fission and fusion reactions respectively for obvious reasons. The well known uranium 235 and plutonium reactions are fission reactions; the thermonuclear reactions of interest are fusion reactions.

There are exceptions to this simple rule of energy being gained by fusion reactions with light elements and fission with heavy elements. Firstly there are minor maxima in the binding forces among the light nuclei and nuclei just above these maxima can undergo fission. Also a fusion reaction involving the addition of just one particle (proton or neutron) to a nucleus can occur with heavy elements because there is a net gain in binding energy despite a decrease in the average binding energy per particle.

Hydrogen Reactions

There are many light element reactions which yield large quantities of energy. Those which are caused by neutrons can be ruled out because, unlike the uranium and plutonium reactions, no further neutrons are produced to maintain the supply of neutrons. The interesting reactions are those which occur when two atomic nuclei collide. These reactions differ from those induced by neutrons in that they do not occur to any appreciable extent at low energies; this is because of the repulsion caused by the positive charges on the nuclei. The electric force has a longer range than the nuclear attractive forces and so the nuclei must have sufficient kinetic energy when they approach to overcome the electric field. The most interesting reactions are those which have the largest cross-section (that is, largest probability of occurring) at moderate energies because these will need the lowest temperature to produce a useful reaction rate. These will be the reactions between the lightest nuclei because they will have the smallest electric charges and minimum electric repulsion. The following are the most probable reactions at low energies:—

$$\left.\begin{array}{l} H^2 + H^2 \longrightarrow H^1 + H^3 + 4\ \text{MeV} \\ H^2 + H^2 \longrightarrow n + He^3 + 3{\cdot}25\ \text{MeV} \end{array}\right\}$$
$$H^2 + H^3 \longrightarrow n + He^4 + 17{\cdot}6\ \text{MeV}$$
$$H^3 + H^3 \longrightarrow 2n + He^4 + 11{\cdot}3\ \text{MeV}$$
$$He^3 + H^3 \longrightarrow H^1 + He^4 + 18{\cdot}3\ \text{MeV}$$

These are all fusion reactions. The raw materials are deuterium, tritium and helium 3. Of these, only deuterium occurs naturally, but the other two are produced as by-products in the two deuterium reactions and the neutrons produced in three of the reactions can be used to breed further tritium by absorbing them in lithium.

Even deuterium is a rare isotope—about 2 parts in ten thousand of natural hydrogen—and one may wonder if this is a practical fuel. The answer is that about 800 kWh are required to separate a gram of deuterium from ordinary water, whereas if this amount of deuterium is "burnt" in a reactor, 24,000 kWh of energy are liberated, so there is a large margin of gain. Since the reaction energy is several million electron volts, whereas chemical reactions liberate only a few electron volts, it is easily seen that there is considerably more energy in the deuterium of a given volume of ordinary water than in an equal volume of petrol. From this it has been estimated that there is enough deuterium in the sea to supply the world's power at a thousand times the present rate for a million years. This almost unlimited solution of the world's power problems is the goal which spurs scientists and engineers in their quest to produce a controlled thermonuclear reaction.

The cross-sections for the above reactions have a variation with relative energy (E) of the particles which is given by the formula:

$$\sigma = \frac{A}{E} \exp(-BE^{-\frac{1}{2}})$$

where A and B are constants which differ for the various reactions. Because of the exponential term, the cross-section increases rapidly with energy at low energies. It has a maximum value and this occurs in the range 10^6 to 2×10^6 electron volts for the above reactions.

Why Thermonuclear Reactions ?

The reactions listed above can be produced without difficulty in a very simple high-voltage accelerator by bombarding a target containing one type of nucleus with a beam of another type. In fact they have been studied at voltages down to 10 kV, the voltage of a domestic television set. Why cannot a simple accelerator be used as an energy source? The answer is that although the cross-sections for these reactions are large as nuclear cross-sections go, they are still very much less than the cross-section for

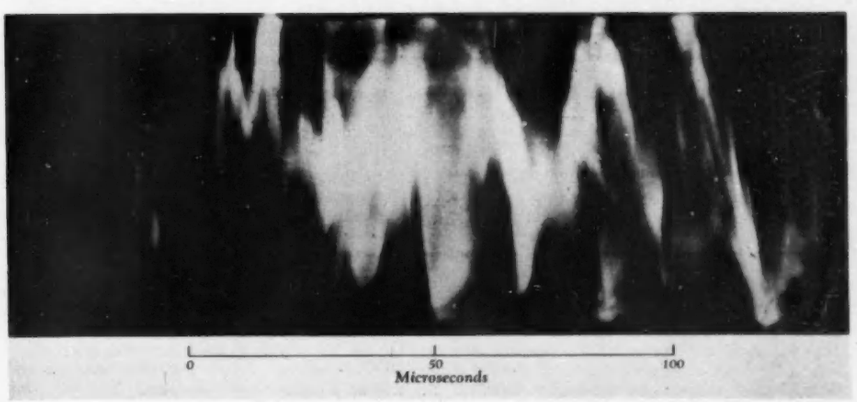

Fig. 2 Streak photograph of an 80,000 ampere discharge in heavy hydrogen, showing violent wriggling of discharge. The tube diameter is 12 in.

THE PROSPECT OF UNLIMITED POWER FROM SEA-WATER

the other types of collisions which can occur, namely ionisation, excitation and elastic scattering collisions with the cold target particles, all of which slow down the beam particles. An ionised gas for the target would rule out the first two types of collision but elastic scattering would still be too large unless the gas were very hot, and in this case the gas would produce its own reactions anyway. As a result with cold targets most of the bombarding particles waste their energy without causing a nuclear reaction. The energy (ω) liberated by the few reactions which do occur is very small compared with that put into the beam (W). Energy has been gained, of course, in that ($W + \omega$) heat energy has been generated in the target, but this heat must be turned into electricity to maintain the accelerator. Because of the inefficiency in this conversion, only about $(W + \omega)/3$ electrical energy can be obtained and this energy is quite inadequate to maintain the accelerator because ω is small compared with W.

If, on the other hand, the fast particles are constituents of a hot ionised gas, the elastic collisions will not cause any wastage of energy; they will merely transfer energy backwards and forwards between the particles, the number of fast particles with a given velocity remaining constant.

Temperatures and Densities Required

The rate at which a fusion reaction will occur for a given temperature is given by:

$$r = n_1 n_2 \langle \sigma v \rangle$$

where r is the number of reactions per second per unit volume, n_1 and n_2 the densities of the two gases, v the relative velocity of two colliding particles and σ the nuclear cross-section referred to above. The brackets signify an average value of the product σv, the average being taken over all possible relative velocities that can occur between particles in the gas because of the Maxwellian distribution of velocities. The averages have been calculated by W. B. Thompson.[11]

The table shows the number of reactions which will occur per cubic centimetre per second in an equal tritium-deuterium mixture at various temperatures. The lower figure in each square is the power generated in watts per cubic centimetre. The most striking thing is the extremely rapid variation of the reaction rate with temperature at the lower temperature. The figures show that a temperature of at least 10^6 deg. K. is required to produce a detectable number of reactions and there is little hope of getting even a single reaction below this. All other reactions need still higher temperatures than this particular reaction. Temperatures in the range 10^7 to 10^8 deg. K. are needed to give a useful power for an energy source. The reaction rate varies as the square of the particle density but it is easily seen that densities greater than those listed cannot be envisaged because a density of 2×10^{18} (one tenth of atmospheric pressure at room temperature) at 10^8 deg. K. is 3×10^4 atmospheres!

TABLE.—*Reaction Rates for Tritium-Deuterium Reaction per Cub. Cm. per Sec.*

Number of deuterium or tritium atoms per cubic centimetre. (1 : 1 mixture ef deuterium and tritium)	Temperature, deg. K.				
	10^5	10^6	10^7	10^8	10^9
10^{14}	$1{\cdot}2 \times 10^{-22}$ ($3{\cdot}4 \times 10^{-24}$)	5×10^{-3} ($1{\cdot}4 \times 10^{-10}$)	$9{\cdot}3 \times 10^{7}$ ($1{\cdot}6 \times 10^{-6}$)	$8{\cdot}5 \times 10^{11}$ ($2{\cdot}4$)	$2{\cdot}6 \times 10^{12}$ ($7{\cdot}3$)
10^{16}	$1{\cdot}2 \times 10^{-18}$ ($3{\cdot}4 \times 10^{-20}$)	5×10^{2} ($1{\cdot}4 \times 10^{-5}$)	$9{\cdot}3 \times 10^{11}$ ($2{\cdot}6$)	$8{\cdot}5 \times 10^{15}$ ($2{\cdot}4 \times 10^{4}$)	$2{\cdot}6 \times 10^{16}$ ($7{\cdot}3 \times 10^{4}$)
10^{18}	$1{\cdot}2 \times 10^{-14}$ ($3{\cdot}4 \times 10^{-16}$)	5×10^{6} ($1{\cdot}4 \times 10^{-1}$)	$9{\cdot}3 \times 10^{15}$ ($2{\cdot}6 \times 10^{4}$)	$8{\cdot}5 \times 10^{19}$ ($2{\cdot}4 \times 10^{8}$)	$2{\cdot}6 \times 10^{20}$ ($7{\cdot}3 \times 10^{8}$)

The top figure given in each square is the number of reactions per cubic centimetre per second. The lower figure in parenthesis is the power generated in watts per cubic centimetre.

Need for Containment

To produce useful power, therefore, in a fusion reaction, a gas with density of the order 10^{16} must be heated to a temperature in the range 10^7 to 10^8 deg. K. It has already been mentioned in the introduction that such a gas must be kept away from any material walls because this temperature is several orders of magnitude in excess of the highest boiling points. The vapours liberated would not only cool the hot gas by sharing its energy but would lead to much higher radiation losses (see below).

There are other equally compelling reasons why the gas must be kept from the walls. One is the fact that if a gas with $n = 10^{16}$ and $T = 10^8$ deg. were adjacent to a wall the hot particles would hit the wall at such a rate as to deliver about 10^{10} watts per square centimetre. Even neglecting the vaporisation that would be caused, it would require a sphere of reacting gas with diameter 80 km. in order to produce sufficient reaction energy in the volume to supply the energy loss from the surface.

Again the cross-section for a reaction even at high temperatures is very small and the distance a particle will travel on the average before it makes such a reaction at $n = 10^{16}$ is 10^3 km. With reacting volumes appreciably less than this, most of the hot particles would be lost to the walls before reacting and the device would not work for the same reason as was given above for directed beams. For this reason alone one must apply a magnetic field to curl up the paths of the particles to enable them to cover distances of 10^3 km. in a reasonable size container before being lost to the walls.

J. D. Lawson[12] has dealt with this problem by considering the time for which the particles must exist in the hot gas. If t is the mean life time in seconds of a hot particle before being lost to the walls (or the life time of the whole hot gas if it is heated intermittently) then the product nt must be greater than 10^{14} for a useful power reactor with the TD (tritium-deuterium) reaction and 10^{16} for DD. With $n = 10^{16}$ the particles must have lifetimes of 10^{-2} and 1 second in the two reactions, respectively. To the gas-discharge physicist these seem almost impossibly long times.

To achieve a successful thermonuclear power reaction an electromagnetic field is therefore required which will cause a large drop in either the density or the temperature between the reacting part of the gas and that near the walls, so that the amount of power reaching the walls is greatly reduced. A low density near the walls means a low rate of loss of particles to the walls and hence the life time of an average particle will be long. In the case of a temperature gradient the hot particles at the centre will have a long life time before losing their energy to the surrounding cold particles, though the life time of the colder particles near the walls will be proportionately shorter.

Radiation Losses

An electromagnetic containing field, if successful, will reduce the heat losses caused by processes equivalent to heat conduction and convection; it will have no effect on losses due to radiation. The physicist knows of no way of stopping photons except by absorbing or reflecting them by matter. (A photon is a quantum of light energy.) This would involve a considerable amount of matter when in the form of a hot gas at the temperatures considered here, a depth of gas greatly in excess of any reasonable size for a reactor. It is, therefore, necessary to consider what these uncontrollable radiation losses will be.

If a gas at 10^8 deg. were in complete thermodynamic equilibrium there would be a very high energy density of electromagnetic radiation passing backwards and forwards in the gas. The energy radiated by such a gas would be given by the Stefan-Boltzmann law and proportional to the fourth power of the temperature. It would be astronomically large at 10^8 deg., but because most of the photons produced in the gas will escape without being absorbed or scattered, there is no chance of this density of radiation building up. The loss of energy by radiation will thus depend on the rate of conversion of the kinetic energy of the particles into radiation. This happens in a completely ionised gas whenever the charged particles are decelerated as a result of collisions. This radiation, which is known as Bremstrahlung, fortunately occurs at a rate which is much less than blackbody radiation, the equilibrium radiation governed by the Stefan-Boltzmann law. The power radiated per unit volume is given by the following equation.

$$P = 1{\cdot}4 \times 10^{-34} n^2 T^{\frac{1}{2}} \text{ watts per cub. cm.}$$

This varies in the same way with density as the power generated by the reactions, but much more slowly with temperature. The reaction power becomes greater than that radiated at $T = 5 \times 10^7$ deg. K. for the TD reaction and 3×10^8 deg. K. for the DD reaction. One has to go to only slightly higher temperatures to liberate sufficient excess of energy to heat the fresh fuel coming in and maintain the reaction.

The reaction energy appears as kinetic energy of the new particles formed in the reaction. Some of these are charged nuclei and some neutrons which have no charge. The charged particles receive two-thirds of the energy in the DD reaction and one-fifth in the TD reaction. It should be possible to trap these particles in the gas with their energy but the neutrons will escape giving their energy to the cooling material surrounding the reactor. If the charged particles are trapped, the reactor can maintain itself as far as heating is concerned, but electrical energy will still be required to produce the confining electromagnetic fields.

The above formula for Bremstrahlung radiation is for hydrogen where the positive ions have one electronic charge. A positive ion having Z electronic charges causes more collisions with higher deceleration leading to Z^2 times as much radiation. Because of this the proportion of impurity gases in the system must be kept small to prevent the radiation losses becoming too large.

Electromagnetic Containment

Only a few electromagnetic field configurations have been suggested to contain the hot gas. Most of these are based on the fact that if an electric current is flowing in a gas, a force can be exerted on it by a magnetic field. The force acting on unit volume is Hj, where H is the magnetic field and j is the current density, and the force is directed at right angles to both H and j. A configuration of currents and magnetic fields is required such that this force is everywhere directed away from the walls of the containing vessel. The force will compress the ionised gas until it is balanced by a pressure gradient $\frac{dp}{dx}$. This pressure gradient gives the

required reduction of density or temperature at the walls.

The simplest configuration of H and j which satisfies this condition is that which is produced by merely passing a high current through the gas. Considering a cylindrical tube containing the gas and a large current flowing parallel to the axis, the lines of magnetic field produced by the gas current are circles concentric with the cylinder. The orthogonal direction to these two vectors is the radial direction at any point and the force is easily checked to be radially inwards. The discharge thus tends to constrict towards its axis and away from the tube walls. This tendency for parallel electric currents to attract one another is called the pinch effect and has long been known to electrical engineers.

The pinch effect reduces the pressure of the ionised gas near the cylindrical wall but not at the ends. To solve the problem of losses of heat in the axial direction, the discharge tube can be bent into a circle and closed on itself to form a torus, thus removing the ends. Electromagnetic induction (that is transformer action) can be used to generate the current in the ring. The toroidal discharge has been suggested independently by many workers as the means of producing a controlled thermonuclear reaction.

A simple and fundamental relation is obtained for the pinch effect by equating the radial pressure gradient to the inward force Hj. This leads to the result that in order to balance the magnetic force, the temperature of the gas must rise to at least $I^2/4Nk$, where I is the total gas current, N the number of atoms of gas per unit length of the discharge and k Boltzmann's constant. As an example, if I is 10^5 amperes and N is 10^{16} per cm. then T must be at least $1{\cdot}8 \times 10^7$ deg. K. The table shows that a substantial reaction rate will occur at this temperature. A current two or three times as great is required for a useful generation of power. Thus 10^5 to 10^6 amperes is the current range required.

Instabilities

If all that is required is a gas discharge of 10^5 amperes, how is it that a controlled thermonuclear reaction was not demonstrated years ago? Currents of this order can be produced in a low-pressure gas for short periods of time without difficulty by discharging a bank of condensers through a primary winding coupled with a toroidal discharge tube. The answer is that the pinched discharge is unstable. This prevented early success being achieved in this field.

The first type of discharge oscillation at high currents was discovered by Cousins and Ware[13] who found that when a large electric field was applied to a gas it became ionised and then constricted so rapidly due to the pinch effect that shock waves were set up and a series of alternate contractions and expansions of the discharge channel occurred. Fig. 1 shows an example of this behaviour. It is a smear picture of the discharge as seen through a narrow slit across the tube, the image of the slit being swept across the film by means of a rotating mirror. These oscillations die out and are not too serious, in fact, they have certain advantages such as helping to heat the gas. The constricted discharge exhibits other oscillations which do not decay. The most common of these is the "wriggle" instability of the discharge, which is caused by a slight kink in the discharge channel growing in amplitude due to the larger magnetic field on the concave side. This instability was predicted by two American physicists, Kruskal and Schwarzschild,[14] and was first demonstrated in this country by Carruthers and Davenport at Harwell.[14] Fig. 2 shows a rotating mirror smear photograph taken at A.E.I. of an 80,000 ampere discharge in hydrogen. The violent wriggling of the discharge is very apparent. Since the channel frequently has velocities greater than 10^7 cm. per sec. (200,000 m.p.h.!), this is probably one of the fastest objects ever photographed. This instability throws the discharge against the tube wall and leads to unacceptable heat losses and also to serious vaporisation of the walls, causing pollution and quenching of the hot gas.

The controlling of these instabilities is the most important problem presented by the pinch effect approach to a controlled thermonuclear reaction. Instabilities may be the main problem connected with all approaches.

Other Problems

Materials.—The walls of the containing vessel for the discharge must be able to withstand the intense conditions presented by the hot gas. In the presence of an unstable discharge the walls undergo bursts of intense bombardment by high-energy particles and few, if any, materials can withstand this treatment without vaporising. Wall materials are a very serious problem with an unstable discharge. If the wriggling of the discharge can be controlled, the walls will have to withstand only the Bremstrahlung radiation and a small degree of particle bombardment. This is within the capabilities of known materials. A solution of the instability may, therefore, solve the material problem.

Heating the Gas.—In the pinch effect type of approach, it would appear at first sight that the large currents generated in the gas, in addition to giving the controlling fields, would provide ample heating to raise the temperature to the required value. Unfortunately the electrical conductivity of an ionised gas is proportional to $T^{\frac{3}{2}}$ and at high temperatures it becomes a very poor conductor, at 10^8 deg. being about 10 times better than copper. The heat generated by the current is therefore only a modest amount at high temperatures. It is enough to supply the Bremstrahlung radiation losses in certain cases, but it leaves little room for other losses and the rate of rise of temperature will be slow at high temperatures. More efficient methods of heating the gas at high temperatures are therefore being considered.

Measurements.—In experiments with these high-current discharges, it is important to be able to measure such quantities as the temperature and density of the gas. The measurement of these quantities in low-current discharges is difficult but at high currents it is very much worse. The methods used with low currents cannot be applied because the gas emits no atomic spectra and any probes inserted into the hot gas would vaporise. Once temperatures sufficiently high to produce reactions are achieved, the number of neutrons emitted will provide a measure of temperature, but meanwhile one must rely on the limited Bremstrahlung radiation or pass radiations through the discharge. Devising these new methods of measurement is taxing the physicists' ingenuity.

Conclusions

The physics of thermonuclear reactions shows that there is no fundamental reason why the almost limitless energy stored in the heavy-water component of the sea cannot be tapped. To liberate this energy, temperatures of 10^8 deg. must be produced, and the hot gas must be prevented from coming into contact with any material walls by electromagnetic fields. There are serious problems associated with this confinement which have yet to be solved.

These problems are being pursued on a substantial scale in the three major countries of the world. There is little doubt that much progress will be achieved in the next few years. It is basically impossible to predict how long it will take to master an unsolved problem, but some of the most experienced scientists in the field have made guesses, and times as low as five years have been stated for the demonstration of a useful reaction.

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Background

Previous references to fusion work which have appeared in ENGINEERING are as follows: vol. 180, page 234, 1955; vol. 181, page 318, 322, 355 and 409, 1956; vol. 182, pages 124 and 187, 1956; vol. 183, pages 58, 121, 217 and 540, 1957; vol. 184, pages 29, 156, 347, 474 and 538, 1957.

VACUUM TECHNIQUES FOR ATOMIC ENERGY WORK

Vacuum techniques are used in two distinct fields: applications where a vacuum is required as an essential part of a process; and applications in which vacuum techniques are merely used to ensure the tightness of plant (which may not finally be required to operate under high vacuum conditions). In a paper by Dr. H. Kronberger presented at a meeting of the Institution of Mechanical Engineers on November 8, examples were given showing how vacuum techniques are used in a uranium 235 diffusion plant, in plant handling liquid metals at high temperature, in experimental work for pressurised-water reactors, and in the testing of the Calder Hall heat exchangers. Basic design rules were enumerated and illustrated by examples of flanges, valves, and other components used in the applications mentioned above. Vacuum testing methods were also discussed. The charcoal-Pirani technique has been favoured for most applications; tests can be carried out on components before they are degassed and clean; equipment and operation are simple. The management of vacuum work was discussed and a method of quality control by means of binomial distribution charts described. The paper was entitled "Vacuum Techniques in the Atomic Energy Industry," and the meeting was held in conjunction with the British Nuclear Energy Conference.

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B.N.E.C. ADMITS FUEL INSTITUTE

At a recent meeting of the Board of the British Nuclear Energy Conference, the Institute of Fuel was admitted to membership of the B.N.E.C. The purpose of the Conference is to co-ordinate the activities of the constituent members in the field of nuclear energy; meetings are held and a journal is published. The eight constituent societies of the B.N.E.C. are the Institutions of Civil, of Mechanical, of Electrical, and of Chemical Engineers; the Institutes of Physics, of Metals and of Fuel, and the Iron and Steel Institute. The offices are at 1 to 7 Great George-street, London, S.W.1.

Companies in the News

Strength Through Mergers

The importance of mergers to achieve efficiency in an industry was only recently stressed by Lord Weeks, when he advocated amalgamation of aircraft firms. Recent statements on the need to conserve our resources in the field of research and development and therefore avoid overlap have been made by many people in positions of leadership. But there has since the war been a vigorous trend towards mergers and the establishment of groups. Some of them have set up central engineering departments and most have benefited from the advice and leadership of technologists appointed to the board or staff of the parent company. Increasingly it is becoming clear that the small company requires very special operating conditions to prosper —and mere survival is no solution from the national point of view.

Some of the strongest companies in this country who are at the forefront of technical advance have either merged or concluded technical assistance agreement with United States firms. In this manner there is usually a most valuable exchange of basic knowledge, generally provided by the British firm, for production and marketing know-how where the Americans excel. The announcement of a new association between James North and Sons, who are the largest makers of protective clothing in Europe, with Jomac Incorporated of Philadelphia, is a good example of the type of agreement which confers on the member firms an immense technical advantage in research as well as a most comprehensive world network of manufacturing and marketing units. Ultimately this may well be the way of integrating the west European industrial effort as member countries advance towards a free trade area. Something of the kind will almost certainly be required to withstand the kind of competitive onslaught which can be expected from the Soviet Union, China and other countries in the East during the next decade.

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Increase in Rhodesian Pig Iron Capacity

Further details were released last week of the expansion programme of the Rhodesian Iron and Steel Company (Pty.) Limited, foreshadowed last March when the agreement was reached to de-nationalise the Rhodesian Iron and Steel Commission. It will be remembered that this agreement provided for the transfer of the assets of the Commission to the new company sponsored by United Kingdom steel producers and Rhodesian and South African mining and finance houses.

It was announced last week that Head Wrightson and Company S.A. (Pty.) Limited, of Johannesburg, have been awarded the contract for the supply of a 16 ft. diameter blast furnace. This company have also secured the order for the 3 million cub. ft. per hour gas-cleaning plant required to clean the gas produced by the new furnace and the two smaller existing furnaces. The plant will be designed by Head Wrightson Iron and Steel Works Engineering Limited in collaboration with John Miles and Partners of Bulawayo, the consulting engineers to the Rhodesian Iron and Steel Company.

Three hot blast stoves 20 ft. in diameter by 100 ft. high are to be installed. After leaving the blast furnace and passing through primary and secondary dust catchers of a centrifugal type, the gas from the new blast furnace will be discharged into the main where it will join that from the existing blast furnace and be conveyed to the new gas-cleaning plant. The latter will comprise two 12 ft. diameter wet scrubbers followed by three Head Wrightson Research electrostatic precipitator units, each 18 ft. in diameter. The plant will also include an 84 ft. diameter Dorr clariflocculator which will extract the major part of the entrained solids from the effluent leaving the gas-cleaning plant and deliver substantially clean water for recirculation. Head Wrightson Processes Limited will also supply an induced draught cooling tower for cooling this water before re-use. The bulk of the plant is to be manufactured in the Union of South Africa and Southern Rhodesia.

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Henry Simon Stock on Offer

The first sentence of the History and Business section of the prospectus of Henry Simon (Holdings), who are issuing over 1 million ordinary shares of 5*s*. each at 16*s*. 9*d*. per share, begins with these words: In 1875 Mr. Henry Simon established in Manchester a flour milling engineering business which took the lead in the next twenty years in converting the British flour milling industry from millstones to automatic roller mills. The success of that revolutionary change was such that under Mr. Henry Simon the business became the most important of its kind in the country and a substantial exporter of flour milling machinery to the Commonwealth and South America. To-day the company's president is the son of the founder, Lord Simon of Wythenshawe. In these 80 years the business has grown into many new fields, most of them allied to the original flour milling business (now carried on by Henry Simon Limited). Simon Handling Engineers (incorporated 1934) manufacture bulk handling plant for the loading, unloading, handling, blending, processing and storage of grain, coal, ores, chemicals, alumina, phosphates and oil-seeds, and for the handling of boxes, packages and other individual articles. Turbine Gears (1931) have grown from a small engineering concern acquired in that year to " tailor-made " gears and gear units for cement plant, rolling mill equipment, for the mines and other industries. The group have strong links with Simon-Carves.

The directors' report on current trading and future prospects is a confident document. They report that orders already in hand and in prospect should enable the Group to maintain its present level of operations for the next two years and that, subject to changes in the climate of trade, there is every prospect of a satisfactory demand for products of the Group for many years to come. This is a fine story and a fitting forecast. One is tempted to speculate whether a business similarly founded in 1957 could ever reach the immense spread and potential pre-eminence that Henry Simon has achieved. The answer is almost certainly in the negative, for the effort required from one man and his son appear too much even for the most gifted.

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Recovery—for How Long?

The latest of the motor companies to announce their results—British Motor Corporation for the year to July 31 and Standard Motor Company to August 31—confirm that the phenomenal recovery by Ford during the first half of this year was no isolated instance. In the first half of their financial year B.M.C. made a loss but for the full year a profit of £11·22 million. Output figures for the industry as a whole suggest the recovery began in April and only four months of it are therefore reflected in the profit figures. These compare with £14·36 million the previous year and £22·33 million in 1954/55. Standard record an increase in their profits from £3·01 million to £3·15 million. Like B.M.C. they suffered from poor trade in the first months of their financial year followed by " substantial profits " in the last months. Despite their large output of agricultural tractors they seem to be affected by fluctuations in car demand in the same way as the large car manufacturers.

The recovery of the summer months, which appears to have been fully reflected in export sales and is being maintained, will ensure for most companies a year at least as good as the last one and most of them should do much better. It remains to be seen how far the latest measures of the Chancellor will affect home demand in the spring, and also on how far serious labour troubles can be avoided. It would be unrealistic to plan ahead or make any forecast without taking these factors into account. Taking a longer view, motor manufacturers appear to be in for a tough time. Their best markets are increasingly being subjected to restrictions, either physical or financial, and the downward trend in raw material prices must affect the purchasing power of Australia, New Zealand, South Africa, Canada, Scandinavia and many others.

Heavy vehicles are once again moving into a period of falling sales. John I. Thornycroft's chairman, Sir John Thornycroft, mentions the fall in military requirements, tightening credit in the home market and a combination of local manufacture and the shortage of sterling abroad as reasons for expecting a fall in sales next year. But, he says, heavy specialist vehicles are unlikely to be affected to the same extent. Even then, the ability to provide long-term credit to those countries whose sterling reserves have been depleted recently, is likely to be all-important in the competitive struggle which is developing.

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"Some Curtailment" in Tubes

The results of Tube Investments for the year to July 31 are better than the directors appeared to expect last November. Their chairman, Mr. Ivan Stedeford, then said that the 1955/56 records in turnover and profits were " unlikely to be challenged for a while." Nonetheless, profits are up £1·03 million to £15·65 million. Once again the assessment of future prospects is cautious: " during the first quarter of the current financial year there have been indications of a slackening in demand. The outlook is uncertain but if the present trend continues it may involve some curtailment of operations." The group supply a very wide range of tube to practically every manufacturing and contracting industry. Their incoming orders are therefore a sensitive barometer and they should be in a better position than most to forecast changes in the industrial climate.

Wellington Tube Works take a somewhat more sanguine view of their own prospects particularly in the long term. Their turnover for the year to June 30 was slightly up on the previous year but trading profits were down by £94,000 to £839,000, due to increased manufacturing costs. They are experiencing a slight but steady fall in the demand for gas type tube but take the view that this type of product is inevitably subject to short-term fluctuations and that " all available evidence " indicates a substantial and increasing long-term demand. Mr. Douglas W. Turner, their chairman, announced that the company were building a new factory to produce polythene tube for cold-water uses, though he did not expect competition from plastics tube to affect greatly the market for G.L. tube. They are committed to a capital expenditure of £290,000 for the current year, an increase of £50,000 on the year under review.

Wellington Tube, unlike T.I., make finished products and operate both a fabricating department and a heat exchange division where sales of tubular heat exchangers have been " an outstanding feature " of the past year. What the reports of both companies indicate is a fall at the present time in general industrial demand. This is likely to be the problem of the coming year.

Letters to the Editor

COOLING TOWER PACKINGS

SIR, I note from Mr. Derek J. Tow's letter in ENGINEERING, October 25, page 520, in which he comments on the article published in your issue of September 13 (page 332), that he considers that the comments made there regarding extended surface packing are misleading.

In spite of Mr. Tow's observations, the fact remains that where low re-cooled water temperatures are required, associated with close approaches to the wet-bulb air temperature, the extended-surface type of packing has largely superseded the splash-bar type of fill for cooling towers. Mr. Tow is quite correct in saying that the extended surface packing has a greater cooling capacity for a given height than the splash type tower, resulting in lower pumping costs. His remarks, however, regarding costs of this type of packing are extremely wide of the mark, as modern timber fabrication methods and tower erection practice allow us to market cooling towers at very competitive prices. The high efficiency of the extended surface type of packing enables the required cooling to be achieved over a smaller plan area which, in turn, reduces the cost of the catchment tank under the tower; a point which is very often overlooked when appraising cooling tower tenders. Mr. Tow also omits to mention that the air pumping charges are much lower in the case of towers packed with extended surface packing, as opposed to those fitted with splash bar packing.

Mr. Tow's remarks about the operational efficiency of extended surface packing also show distinct bias. Towers fitted with extended surface packing have been operating in this country now for over ten years and we have yet to hear of any complaints of tower performance falling off due to the presence of oil in the circulating water. The fact that a great many grid packed towers have been operating successfully for years in the petroleum industry, where oil from time to time leaks into the circulating water system, and where any falling off in the performance of the tower duty would have repercussions on the various processes carried out in an oil refinery, give ample evidence that Mr. Tow's remarks are nothing more than unsubstantiated sales propaganda.

It is true that the water distribution system on an extended packed tower must be accurately aligned and, naturally, the manufacturers of this type of packing allow in their design for easy methods of re-levelling the water distribution in the unlikely event of settlement. There is little evidence to show that water flowing through a trough system tends to foul up more readily than that flowing through a pipe-distribution system. On the contrary, we have recently been asked by one large cooling tower user in a nationalised industry to replace their pipe-sprayer systems with open-trough systems, as operational experience has shown that pipe-sprayer systems need more attention than open-trough systems.

With regard to inspection of the two types of packing, it is just as easy to inspect a tower packing from its underside as from its top. The sections of timber employed in extended surface packed towers are of sufficient size to give longer life than the packings normally employed in splash towers, due to the fact that they are only spanned over 2 in., whereas a splash bar may well have to span 6 ft., and any slight deterioration in its condition will rapidly cause the bar to sag, with consequential deterioration in performance.

In view of the very large number of repeat orders manufacturers of the extended surface packed towers have enjoyed, there is very little doubt that both from the theoretical thermal-efficiency and practical operational-efficiency viewpoints, the extended surface packing enjoys a marked superiority over the splash packed tower, where low re-cooled water temperatures and close approaches to the wet-bulb temperature are required by discriminating operators. In conclusion, I may add my company design and supply splash packings where an economic case can be made for them.

Yours faithfully,

E. A. HOWE.

Film Cooling Towers (1925) Limited,
Brentford.
October 29, 1957.

"THE FULL PLASTIC MOMENT"

SIR, Those persons who have given any serious attention to the plastic theory of structures will realise how grossly your correspondent Mr. A. N. Procter, in his letter on page 487 of your issue of October 18, misrepresents the significance of the approximations that are made in it. Nevertheless, it is necessary to make reply, since casual readers may be led to believe that there is something " phoney " about the theory.

The " theoretical " stress distribution at full plasticity has never been considered as anything more than an approximation. As such, it gives a consistently close estimate of the moment which, if applied to a mild steel beam, will cause a large increase of curvature for a very small further change of bending moment. The increase of curvature is large compared with curvature in the plastic range, being from eight to twenty times the curvature at which yield occurs in the extreme fibres of an initially stress-free beam. In its approximate concept of " plastic hinges," the plastic theory of structures uses this result to provide remarkably accurate estimates of the loads (called the " collapse " loads) at which continuous frame structures undergo large permanent deformations. This has been confirmed experimentally, far more thoroughly than for any other theory of structural behaviour.

Needless to say, the " double rectangle " stress distribution is a simplification. It ignores strain hardening, the discontinuous nature of plastic deformation in mild steel, the restriction of plastic deformation by bi-axial and tri-axial stresses, and the influence of shear forces, to mention but a few of the modifying factors. Careful tests on beams of rectangular, circular and I-section have shown that the general disposition of the zones of plastic deformation is in agreement with theory. More refined treatments have been made allowing for a number of the factors mentioned, and have been shown to lead to results in closer accord with experiment. Within certain known limits, however, the simple plastic theory has been shown to give results sufficiently accurate for engineering purposes. The evidence has been dealt with very fully in *The Steel Skeleton*, vol. II, by J. F. Baker, M. R. Horne and J. Heyman.

The term " confirmed by experiment," applied by your correspondent to the Coulomb theory of the bending of beams below the limit of proportionality, requires careful consideration. The main assumption on which the theory is based (namely that plane sections remain plane) is true only for a member acted upon by a pure bending moment. In the general case, plane sections certainly do not remain plane, and although the stress distribution is almost linear, it is not accurately so, except in a few special cases. Strictly speaking, in a problem so fundamental as this, it is quite meaningless to say that the distribution of stresses has been confirmed even only approximately by experiment, since it is always strains and not stresses that are measured. Elastic theory predicts the *changes* of stress which occur, not the absolute values. When, therefore, one uses elastic theory to calculate a " safe " extreme fibre stress, one is using an imaginary concept, since the actual maximum stress will be quite different due to residual stresses in the beam. On the contrary, the concept of strength used in the plastic theory of structures is a real one. Residual stresses have no influence on the plastic collapse load of a structure, except, possibly, when instability problems are of major importance.

It is a great pity that the impression should be given that the elastic and plastic theories of structures are in rivalry. Speaking generally, the elastic theory has its main application in the calculation of the stiffness of structures (for example, deflection at working loads) while the plastic theory provides a rational means of estimating strength. When dealing with instability problems in continuous structures, a reliable estimate of strength can only be made by considering both elastic and plastic behaviour.

Yours faithfully,

M. R. HORNE.

Cambridge University Engineering Laboratory.
November 5, 1957.

SIR, The introduction of a bending theory that would give an accurate estimate of the maximum capacity of beams of any or of all materials is certainly necessary and, indeed, is rather overdue. There is some doubt, however, whether the new theory should be merely an extension of the elastic theory that was introduced rather a long while ago, when there was not a great deal of accurate information available concerning the mechanical properties of engineering materials.

The original assumption that materials under the action of bending moments were transformed into a system of fibres that were free to expand or contract laterally is " picturesque " rather than " scientific." It is now known that many engineering materials have a crystalline structure and, with the exception of timber, few are actually fibrous, so that it might be expected that timber would give test results comparable with the elastic theory. Using the proportional limit in bending as a datum of comparison, the moments of resistance of rectangular-section timber beams are found to be about 50 per cent. in excess of the limit of proportion in compression, but it could hardly be said that the timber had become " plastic " at stresses well below the ultimate, so that the reasons for the discrepancy must evidently be due to other causes.

The forces between the particles of a solid homogeneous elastic material are now known to be of electro-chemical origin (augmented, possibly, by the molecular magnetic moments). When the materials are strained, these natural forces between the particles tend to resist the straining action. In the interior of the materials, where each particle is surrounded by similar particles, the stresses produced by the strains are likely to have fairly uniform distribution, but around the free surfaces it appears that the electro-chemical charges or lines of force would tend to radiate freely outwards from the surfaces of some materials, although in others, such as glass and thermoplastic materials, they may create surface tensions, as they do at the surfaces of liquids and plastic materials. Thus the thickness and profile of an elastic beam may have a secondary effect, that might conceivably be connected with the transverse strains and distortion under load.

A modern theory of bending might, therefore, be concerned with the forces between and relative motions of the particles of the materials and not with the unpredictable behaviour of hypothetical fibres having mythical properties—or so it would appear to an electrical engineer.

In the present state of our definite knowledge of what actually happens inside an elastic member under the action of bending moments we have no option but to teach the Bernoulli-Euler theory, until a better theory has been established. The extension of the theory to the prediction of ultimate loads has not yet been accepted by the majority of engineers, so that it appears inadvisable to teach it as a theory to students. But there could be no harm in telling them about recent developments, even though the idea of the " full plastic moment " seems to your correspondent to be rather ridiculous.

Yours faithfully,

G. W. DEAKIN.

Horsham.
November 9, 1957.

Metals and Materials

SOVIET METHODS WITH MATERIALS

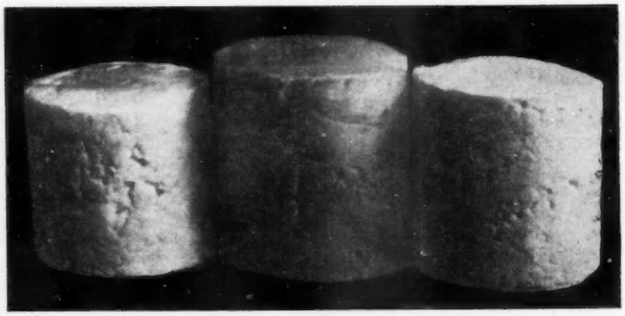

Fig. 1 Petrol contained in a solid emulsion may simplify transport and storage in certain circumstances and relieve the problem of evaporation in hot climates.

FEW ideas are entirely new, but a visitor to a foreign country is almost certain to see some methods that are new to him. Thus to the layman the solid briquettes of petrol displayed in the Academy of Sciences pavilion at the permanent industrial exhibition in Moscow may be a novelty, but to petroleum specialists the process may already be familiar. None of the Soviet methods and techniques discussed below may in fact be new, but some at least are not generally known.

Crust of Petrol

Petrol in solid form has certain advantages. In some circumstances it may be easier to transport or to store, as on expeditions; and the problem of evaporation in hot climates may be largely overcome. A method of producing a form of solidified petrol is described in leaflets available at the Moscow industrial exhibition, and typical briquettes are illustrated in Fig. 1. Formaldehyde emulsifiers serve to disperse the petrol, and the emulsion is solidified by means of oxalic acid. The result is a cake or crust, rather like the cuttlefish found on seashores, which provides a micro-cellular matrix for the petrol. It has the property that should a briquette be cut or damaged a fresh skin forms immediately, preventing evaporation. It is claimed that the petrol can be stored in this form for up to 10 years. The briquettes comprise 95 per cent. petrol and 5 per cent. structure, and to extract the liquid a screw press may be used; the waste would be roughly 7 or 8 per cent. of which 2 or 3 per cent. would be petrol. The process may be employed for paraffin and oils generally.

High-frequency and Ultrasonic Hardening

At Enims (machine-tool research establishment) the use of high-frequency methods have given rapid rates of penetration in surface hardening, reducing the hardening time from 8 hours to 40 minutes. It is thought that the use of this method in conjunction with ultrasonic techniques may reduce the time to as little as 8 or 10 minutes. The agent used is potassium ferrocyanide ($K_4Fe[CN]_6$).

Hardening is frequently carried out on lathes, and at the Hammer and Sickle factory simultaneous broaching and heat treatment is practised.

Flux Bath Welding

A process recently developed in Russia is the flux-bath welding process, and at TsNIITMash (heavy-industry research institute) experiments on the technique are still in progress. The process, which may be used for welding together items as much as a square metre in cross-section, has already been employed in the fabrication of large forging presses and crankshafts. The procedure may be gathered from Fig. 2, which shows two perpendicular vertical sections during the butt welding of two thick plates (1). A baseplate is welded on to the bottom edges of the two plates across the gap, and water-cooled containing plates (2) are fitted along the sides, so enclosing the welding space. Flux is introduced at the foot of this space and the electrode advanced until an arc is struck between the electrode and the baseplate, through the flux. Subsequently heating arises from the electrical resistance of the flux (3) in which the electrode (4) is submerged, and not from an arc. The electrode is constantly fed into the space and the bath slowly fills, with the flux floating on top. To ensure that a high-quality weld is maintained right to the upper edges of the plates extension pieces are fitted, and the upward movement of the electrode continued a short distance beyond the top.

In the case of plate a metre in width and several centimetres thick the gap would be roughly 40 mm. across, and one electrode filler wire would be used for each 60 to 90 mm. of plate thickness; the electrode would move to and fro along the gap. Fig. 3 shows an automatic mechanism for feeding two electrodes into the weld. The wire feed rate is given as 800 mm. per hr. for plate half a metre thick. The bath is said to be at a temperature of 2,000 deg. C., and the current required is 800 amperes per wire. A new approach is being developed at TsNIITMash, whereby a plate electrode is employed instead of a laterally reciprocating wire. The process, which was originated by Academician E. O. Paton, is suitable not only for carbon steels but also for alloy steels.

Magnetic Powder Clamp

A magnetically susceptible powder has been used at Enims in conjunction with an electromagnetic field for gripping delicate parts. The method has been used in an experimental automatic line for the production of piston rings. The rings are held in this way for final machining.

Continuous Casting

Continuous casting is already a familiar process, but even now is still in the development stage. At the Hammer and Sickle Metal Works in Moscow a successful "semi-continuous" plant is in use operating on an incline with a pair of facing link tracks providing the moving mould, as indicated in Fig. 4. The approach has also been tried in America. Good quality billets have been obtained with sections up to 140 mm. square, and up to 100 metres long. The length of a billet is determined by the capacity of the feed vessel, which can contain up to 43 tons of metal. Four to five loads of this kind are poured per 7-hour shift. The billets are cut to release internal stresses and good results have been obtained with stainless steel. The plant is primarily experimental.

Vacuum Chambers for Casting

Vacuum bells 4 metres high are in use at the same factory for removing dissolved gases from molten metal after it has been poured into the ladle. The ladle, up to 10 tons in capacity, is placed on a table in which are vents to air pumps, and the vacuum chamber lowered into position over it. The pressure is reduced to about 20 mm. water gauge. This technique is employed for 4 per cent. silicon transformer steels. It has also been proposed that single rolling mills be contained in similar vessels.

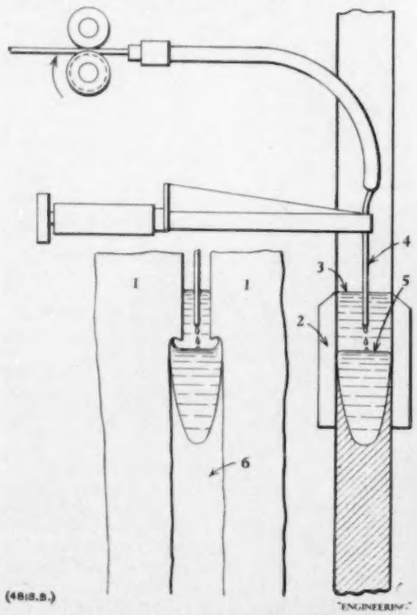

Fig. 2 By means of the flux-bath welding process steel items up to a metre square cross-section may be joined together. Simplified vertical sections of a butt joint are shown to illustrate the process.

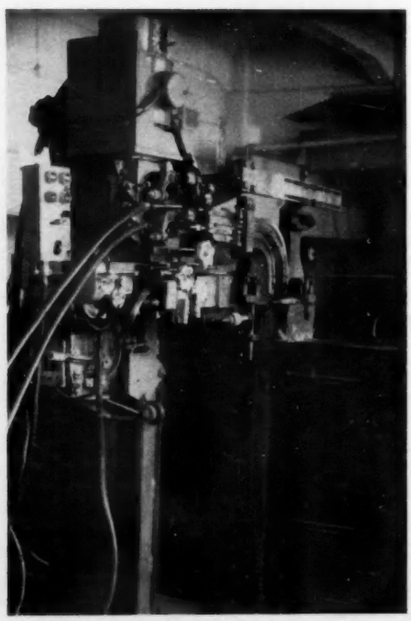

Fig. 3 Experimental apparatus for feeding two wire electrodes into a butt weld between thick plates, using the flux-bath process.

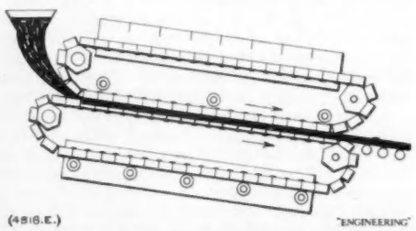

Fig. 4 Continuous casting using series of smooth half-moulds carried on facing link tracks has been successfully practised at the Hammer and Sickle Metal Works in Moscow.

Plant and Equipment

DIESEL-ELECTRIC PORTABLE WINDING ENGINE

Mine Emergency Equipment

In 1940 Walker Brothers (Wigan), Limited, designed a portable winding engine, which could be brought into use at any colliery in the event of damage by hostile action. This machine has since been adopted as an essential part of the mine rescue equipment, while a recent development has been an electrically driven model which incorporates improvements that operating experience has shown to be desirable. Of these new units nine are being manufactured for the National Coal Board in association with John Wood and Sons, Limited, Barley Brook Foundry and Engineering Works, Wigan, and the British Thomson-Houston Company, Limited, Rugby, seven being capable of raising a total load of 5 tons from a depth of 3,000 ft. at a mean rope speed of 12 ft. per sec. and the other two a load of 3 tons from a depth of 1,800 ft. at a speed of 10 ft. per sec.

Power for the trailer-mounted winding engine is supplied from a Rolls-Royce power pack. The trailer is also fitted with standard gauge railway wheels for use on sidings.

The unit, of which illustrations are given on this page, consists of a tractor on which the Diesel-engined generating unit is mounted, and a trailer carrying the electrically operated winding engine and control equipment. The generator is driven by a Rolls-Royce twin engine power pack through a plate clutch, reduction gearing and flexible coupling. The exciter for the generator and motor fields and for the control circuit supplies is mounted on the generator and driven by a V belt. The unit is carried on skids and can either be operated *in situ* or lifted off for employment on level ground.

The trailer is a six-wheeled vehicle, which is equipped with pneumatic tyres for use on the road and standard gauge rail wheels for manoeuvring in sidings. To facilitate movement the front axle can be steered hydraulically from the driver's platform. The winder motor and winding drum with the necessary reduction gearing and flexible coupling are mounted on a bed which is integral with the trailer. The winding drum is of the barrel type with cast steel sides, which incorporate the brake paths. The brakes themselves are of the caliper type and are operated by helical spring nests in compression and levers which are actuated pneumatically. In event of a breakdown in the air supply the brakes fail to safety.

The motor is operated on the Ward Leonard system, the master controller and generator field rheostat being coupled together and worked by the driver's lever. The connections between the generator and motor armatures consist of two three-core cables, terminal boards being provided on both tractor and trailer with socket and bolted plugs. There are also a six-core and a twelve-core cable for the control, auxiliary and alarm circuits. When a load is being lowered regeneration can be used, power being absorbed by the engine being driven above its normal speed.

Protection of the winder is effected by a contactor, which controls an electrically-operated air valve. When this valve is de-energised the emergency brakes are applied. Overloads are controlled by a relay in the main connection between the generator and motor and overspeeds on the Worrall system. There are also an overwind limit switch, a brake interlock switch, engine overspeed contacts and an emergency-stop push button. The exciter is protected by a hand-operated air-break switch. When an emergency stop occurs the motor field is disconnected from the exciter and discharges through a rectifier and resistance. The generator field is also discharged through a resistance and when the driver's lever is returned to the neutral position a " suicide " circuit is closed and the path through the discharge resistance is open-circuited. The master controller has to be returned to the " off " position and the brake lever to the " brakes on " position before the safety contacter can be re-set.

A rope speed indicator, air pressure gauges, warning lamps, buzzers, and emergency stop and safety re-set buttons are mounted on a pedestal in the driver's cabin. Heaters are provided in the motor control cubicle and on the generator and exciter to prevent damage from damp when the winder is being stored. There are also telephones for communication between the driver and the pit top.

COMPUTERS ON RAILWAYS

Two electronic computers have recently been acquired by British Railways. At Swindon the Western Region have installed a Powers-Samas computer to do their paybill calculations; at Derby the London Midland Region have installed a Hollerith 550 computer to simplify the task of inventory control.

Costing £20,000, the electronic computer at Swindon is on rental to British Railways by Powers-Samas Accounting Machines Limited, London, E.C.1, and its use will reduce clerical staff working on paybills at Swindon from 100 to 60, and effect a net annual saving of £10,000. The wages of 10,000 railway workers in the Locomotive and Carriage and Wagon Works are dealt with, and although many varying rates of pay are involved the computer takes all the relevant factors into account when calculating gross pay. Then the computer works out and deducts the income tax due, subtracts the various other deductions and punches the net pay into the card. The computation from " hours worked " to " net pay " takes two seconds per employee. The fully punched cards are then fed into tabulators that print the payslips and payroll.

At Derby the Hollerith computer provides, through a punched card system, rapid information of the issue, receipt, costs, and movement of stores. About 60,000 different items needed for the building and repair of locomotives, carriages, and wagons are dealt with. There are about 3,000 stores movements daily, each of which affects the state of the inventory.

Two classes of documents are available—previous day's invoices and the like, relating to items received into the store; and demand notes and similar documents relating to items issued from the store. From these, information is punched into stores account and recovery cards for receipts, and stores demand cards for issues. After processing the cards—about 12,000 will be involved on average—the machine produces new (closing) balances, which are punched automatically into the new balance cards. At the same time the new quantity balance so punched is compared with a minimum-stock figure—part of the indicative data automatically reproduced from the opening balance card. If the comparison shows the new balance to be below the minimum-stock figure, the calculator draws attention to this by causing a special designation to be punched into the card. A daily material movement record is then drawn up. The computer is made by the British Tabulating Machine Company, Limited, 17 Park-lane, London, W.1.

Continuing **Plant and Equipment**

THERMAL STORAGE HEATER

Thermal storage heaters have recently become popular, owing to the fact that they can take advantage of cheap night tariffs available from the electricity authorities. Dulrae Limited, Griffin-lane, Aylesbury, have announced the introduction of their Supa-Stor storage heater for commercial and industrial applications. The construction is an inner steel container with heat-insulated feet, fitted with two self-contained withdrawable elements. There is a separate non-metallic heat-insulated outer casing with an internal thermostat which is arranged to vary the charging period at night according to the amount of heat withdrawn during the preceding day. The heat storage medium is a powdered material which is packed in after the unit has been installed. The unit measures 2 ft. wide by 1 ft. deep by 2 ft. 5½ in. high and weighs 280 lb. The standard loading is 1,500 watts and the capacity 12 kWh. A time-switch confines its use to the night hours.

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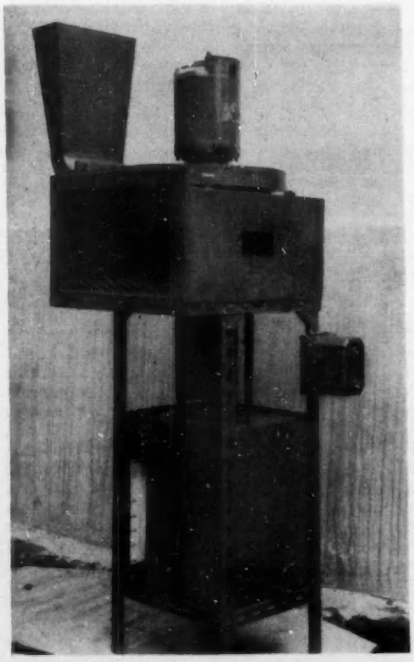
PARAFFIN MIST COLLECTOR

Shown in the accompanying illustration is a unit for suppressing paraffin mist arising during the high-pressure spraying of paraffin in cleaning booths, etc., developed by B.S. Developments, 14 Marlborough-road, Woking, Surrey. The version illustrated, for use with the smaller type of cabinet, has an air throughput of 200 cub. ft. per minute. The mist-laden air is drawn into the grille-protected inlet chamber where it enters the scroll inlet of a static turbo-separator. A high radial velocity is imparted to the mist globules which are thrown on to the walls and fall into the tank as liquid. The cleaned air is drawn upwards through a central core to the fan and thence to the discharge stack. There are no filters requiring removal, and no working parts other than the fan. A number of spray cabinets can be linked together with ductwork, and a central plant with multiple separators can be arranged to recover the paraffin.



The only moving part in this paraffin mist collector unit is the fan. The oil is separated by a static turbo-separator.

TESTING ELECTRICAL ACTUATORS

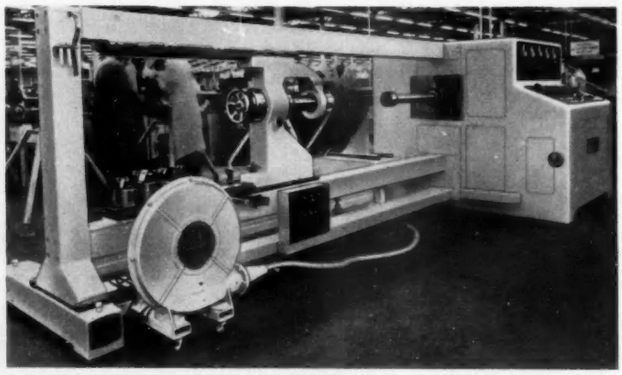
For proving actuators of the linear electrical type which are used for operating aircraft or missile controls and services, a new test rig has recently been installed at the Willesden factory of Rotax Limited. The rig was constructed by Steel Gauges Limited, Birmingham, a firm specialising in the design and manufacture of special-purpose electro-hydraulic machinery. The rig has to be extremely accurate and sensitive, capable of proving the speed of operation, the stability and the all-round performance of the actuator under all operating conditions. The rig is physically capable of testing the largest actuators at present in use and will, in fact, be able to cope with any that are likely to be developed within the foreseeable future.

The control system of the rig is in two separate sections; one is the electro-hydraulic control system of the rig itself and the other an electrical control system identical to that of the aircraft or missile in which the actuators may be used. Test data are obtained by strain gauges, the readings of which are considerably amplified and then read from standard electrical recording instruments.

A double-acting double-rod hydraulic cylinder is able to load the actuators with up to 50,000 lb. total force at speeds up to a maximum of 5 in. per second. A crash stop device, designed to prove the actuator's clutch equipment, is controlled by a solenoid-operated hydraulic valve which, when operated, cuts off the oil supply and locks a solid column of oil between the piston rod of the cylinder and the valve piston. All hydraulic and electric power and control equipment is housed in a control cabinet alongside the rig. Tests are carried out from this position, although there is a remote control point adjacent to the test-piece which enables the operator to make observations at close quarters.

All the hydraulic equipment was supplied by Keelavite Rotary Pumps and Motors Limited, Coventry. Three hydraulic pumps are used in the main circuit. Two are driven by 25 h.p. 1,440 r.p.m. electric motors and displace approximately 32 gallons per minute. A third and smaller pump, driven by a 4 h.p. 1,440 r.p.m. electric motor displaces approximately 2 gallons per minute. The outputs of the three pumps can be used separately or together depending upon the speed of operation required. The small pump is also employed for initially loading the actuators and performing certain static tests. A pilot-operated relief valve controls the pressure of the main circuit up to 1,500 lb. per sq. in. The pilot valve itself is mounted on the operating panel and can be adjusted at will. A solenoid-operated piston valve controls the direction of operation of the cylinder. Solenoids receive their signals from adjustable limit switches actuated by trips on the piston-rod extension of the cylinder. The adjustment is to enable the stroke of the cylinder to be varied according to the size of actuator being tested.

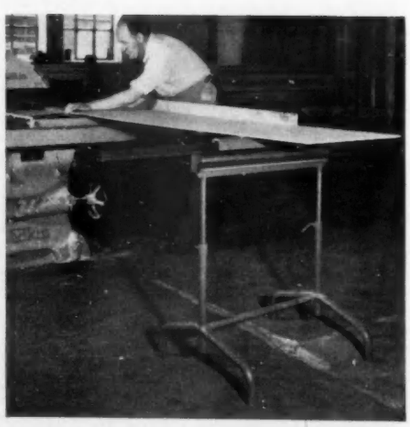
The hydraulic pilot-control system is powered by a pump displacing approximately 7 gallons per minute. A separate relief valve in this part of the system gives a working pressure of 250 lb. per sq. in. Extreme accuracy of operation is essential and for this reason the system is boosted to 30 lb. per sq. in. An oil cooler is incorporated and oil is micro-filtered.



Linear electrical actuators can be hydraulically loaded in this test rig with up to 50,000 lb. total force at speeds up to 5 in. per second.

FEED SUPPORT

The roll-slide support shown in the illustration has been developed by Step Industrial Equipment Limited, 28-30 Sussex-place, London, W.2. It can be used in conjunction with practically any machinery which is working on long or unwieldy pieces of material. It can be used either as a roll support for feeding to a machine lengthwise, or as a slide support when feeding across. The height of the support is adjustable from 22 in. to 44 in. by locking screws on the pillars, and to enable the whole to stand steadily on an uneven floor a foot-operated adjustment is incorporated on the end of one leg. The illustration shows the slide attachment mounted above the roll; the carriage slides on the channel, carrying with it the material being worked on. When it is desired to use the support as a roll, i.e., for feeding longitudinally into the machine, the cross-slide is unclamped and lifted directly off, allowing the work to rest on the roller. Robustly constructed, the support is yet easily portable and so can be used in conjunction with several machines. One advantage is that it enables a single operator to handle awkward workpieces which otherwise would require a second man.

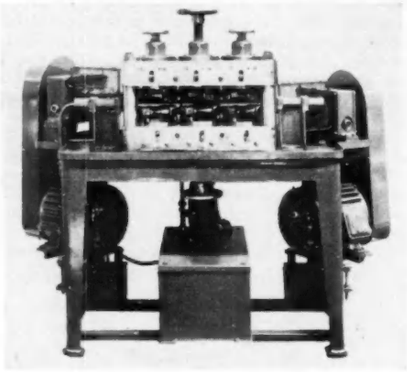


Unwieldy material can be supported by the carrier, both for feeding across, as shown, or for feeding longitudinally when the top slide is lifted off.

TUBE STRAIGHTENING MACHINE

A tube straightening machine designed primarily for straightening Inconel tubes of ½ in. diameter and 0·36 in. wall thickness, is now being made by the Bronx Engineering Company, Limited, Lye, near Stourbridge. The machine is shown in the accompanying illustration.

In action, the tube is held between three pairs of line-contact rolls, all of which are driven. A 1½ h.p. motor drives the three lower rolls, and a second motor of the same capacity drives the upper three. The two motors are placed on a shelf beneath the machine, and the drive is taken from them through totally enclosed gearboxes with a V rope drive. Universal couplings and spindles between the gear drives and the rolls allow adjustment of the latter to be made. The three upper rolls can be adjusted vertically to suit the dimensions of the tube being straightened, while the working deflection



Inconel tubes up to ½ in. in diameter can be straightened on this cross roll machine.

is applied to the centre roll. The two outer bottom rolls are fixed to the base of the machine. The centre lower roll is provided with a vertical adjustment, and in practice is set to grip the tube between it and the upper roll. All rolls have angular adjustment for line-contact setting, and indicators are fitted showing vertical and angular settings. The frame of the machine is of welded steel, and the whole is built to precision limits. The nominal straightening speed is 120 ft. per minute.

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ADJUSTABLE-HEIGHT WORK-BENCH

A compact power-operated work-bench which will lift loads of up to 500 lb. has been developed by Skyhi Limited, Isleworth, Middlesex. The unit is hydraulically operated. By pressing a foot lever it can be raised to the most convenient working height. An air/oil booster provides the hydraulic power to the ram which lifts the platform in one smooth stroke without any manual effort. The bench has been designed for installation either indoors or outside; it can be fitted flush with the floor, or above it, and in the latter case a portable ramp facilitates the positioning of mobile loads on the lifting platform.

Typical uses to which the power bench can be put are the rapid servicing of engines, portable agricultural machinery and motor-cycles or scooters, loading on and off lorries, press tools and innumerable lifting applications in industry.

Fully lowered, the 6 ft. by 2 ft. platform stands 6½ in. from the ground and, carrying a load of 500 lb., it needs an air pressure of 150 lb. per sq. in. to raise it to its maximum height of 33 in.

Management

THE USES OF FILMS

At two recent conferences the uses of films for industrial purposes have been surveyed, and attention has been given to the overall management problem of ensuring that the producers of a film serve up a satisfactory end-product.

The International Scientific Film Association's congress at Amsterdam afforded a valuable opportunity for the free exchange of news and views on the scientific film as applied to all aspects of industry. About 200 attended.

The Russian delegation put forward a valuable suggestion during the congress's second assembly, namely, that the International Scientific Film Association should bring its committees into line with the main directions of scientific filming under headings like "The Popularisation of Science," "Education," and "Research." There is at present a very loose definition as far as the scientific film is concerned, particularly as applied to films as an aid to research. The question what constitutes a research film is continually being asked.

Two definitions of the requirements for such films were the subject of much informal discussion following the film sessions. First, it was felt that a research film is one in which a piece of research is done *by means of film*, in which, from the nature of the case, the film is either the only tool or the best one. Secondly, that a research film is, in addition to the foregoing, a record of a piece of research, usable in teaching, information services, or the dissemination of science by means of the cinema and television.

Several of the films shown in the research sections at the congress would not seem to fit into either of these categories, which is perhaps explained by the fact that scientific film production in different countries varies considerably. Some of the films shown, however, would have been useful for teaching purposes or in the popularisation of science.

During the course of the Congress, which was held under the presidency of Professor Adolf Hübl of Austria, no fewer than 180 films from member countries were screened. British films submitted for showing included *Energy for Europe*, a survey of the energy needs of Europe during the next 20 years and considering the possible sources of this energy; *Criticality*, designed to show workers in atomic energy plants the meaning of criticality and its importance in safety precautions; *Men on the Mend*, portraying activities at the rehabilitation workshop of the Western Region of British Railways at Swindon, where workmen who have been injured exercise their damaged limbs on machines which have been specially adapted for that purpose; and a film on *Work Study and Its Application to Team Work*. Also exhibited were the well-known films, *Atomic Achievement* and *Mirror in the Sky*, the latter of which links the experiments of Heinrich Hertz on the nature of electromagnetic (wireless) waves with the work of Marconi, through the experiments of Appleton, which proved the existence of the Heaviside layer and, later, of the Appleton layer. Another British achievement was the Shell film, *Approaching the Speed of Sound*. This film had the honour of being included in the gala film programme which opened the congress.

Mr. Luc Haesaerts of Belgium was elected President of the Association for 1957-58, and it was decided that the next congress should be held in Moscow at the end of September, 1958, which will be the first occasion when the Association has penetrated the Iron Curtain.

At the Festival of Films in the Service of Industry, recently held at Harrogate, 131 British films were shown. Selected from nearly three times that number they were entered in ten categories, covering public relations and prestige; sales promotion; training inside industry; technical and technological films; sales and dealer training; films for use in schools; health and safety in industry; guidance on careers in industry; industrial productivity; and human relations in industry.

It seems hardly possible to generalise about such a bewildering variety, but certain impressions are persistent: the high quality of modern colour films (even on 16 mm.); the effectiveness of good black-and-white photography; the limited use of cartoon treatment in spite of its obvious capacity both to entertain and to instruct; the dogged adherence of some producers to background music however inappropriate and distracting it may be; and the flat commentary of some professional commentators with immaculate diction but no manifest knowledge of, or interest in, the subject of the film.

In general, the films shown approached their subjects in one of two ways, either by a straightforward presentation of factual information or by its dramatisation in various ways. The purely factual approach was seen at its best in such films as *The Diesel on Rail*, made to assist in the training programme on British Railways; *Single Stack Drainage*, a study of a Building Research Station project for a lay audience; *Structural Steel at our Fingertips*, showing the application of automation to structural engineering; and *Care for Qwerty*, made to show typists simple typewriter maintenance. That such factual presentation need not lack its own element of drama was seen in the beautiful *Foothold in Antarctica*.

The dramatic approach has obvious advantages, particularly in kindling enthusiasm. Notable, therefore, was *The Inquiring Mind* showing career opportunities in electrical engineering and designed for an intelligent, young and enthusiastic audience. The method used there, that of linking good pictures with a carefully written and well-presented commentary, was also used with notable effect in *Test Flight* 263, where impressive and novel equipment, carefully photographed, was presented with a commentary, which, if rather extravagant at times, compelled its audience to be interested.

If it showed much good film, the Festival also raised many problems. There must be closer collaboration between sponsors, producers and film users. To many people, this suggests making (or marring) films by committee. But, in the right circumstances, such close co-operation can produce some fine films, such, for example, as *The Structure and Properties of Steel, Part* 1, *Grain Structure*, made for young workers in the industry with limited educational backgrounds to assist them in courses specifically designed to meet their needs. Too few films have so carefully selected their audiences and taken so much care to meet the requirements of the classroom. Good films require good projection and if they are to be used effectively one would like to see more simple projectors available, so that far more people can make use of films for purposes of training, education, or research. Incidentally, Harrogate was notable for its poor standards of projection; a surprising discovery in a festival of this kind and a notable lapse on the part of the equipment makers.

A few outstanding films and many good ones testified to the ability of British film producers to make films for industry. But it may be wondered whether they are making the right films. Of the 131 shown at Harrogate, 57 were concerned with public relations, prestige and sales promotion, and 34 with various aspects of training. Only seven dealt with human relations and only four offered specific guidance on careers in industry. Cannot industrial sponsors and film producers do more than this, not only to meet the pressing present problems of production and sales, but also the future problems of a new labour force growing up in a more enlightened industrial environment?

Continuing **Management**

Weekly Survey

Training Indian Steel Technicians

During the next four years some 300 Indian university graduates are coming to the United Kingdom to be trained as supervisors for the new steelworks now being built at Durgapur, in Bengal, by ISCON, a consortium of 13 United Kingdom engineering companies formed to carry out the work. ISCON, it may be recalled, is an abbreviation of the Indian Steelworks Construction Company, Limited. The purpose of the training is to give the Indians, all of whom are graduates in mechanical, electrical or chemical engineering, specialised training to fit them for particular posts in the organisation which is being formed to operate the new plant at Durgapur. The first party of 19 trainees are now in this country and, on November 5, they were taken to see the steelworks of Stewarts and Lloyds, Limited, at Corby, near Kettering, Northamptonshire.

The British Iron and Steel Federation and ISCON are advising on the actual training programmes, which will provide not only experience in iron and steel manufacturing processes, but experience in the construction of plant which the trainees will subsequently operate and maintain. The training facilities are being provided by the British steel industry and by the manufacturers of the plant which will be installed in the new works. These facilities, it should be pointed out, are to be a free contribution by the industries concerned. The trainees will be encouraged to work with their hands and live in lodgings in much the same manner as other graduate apprentices do.

This first party of Indian trainees will be followed by other parties, three arriving each year, averaging 25 trainees in each party. The periods of training will vary from six to 12 months, according to each man's experience and the post for which he is to be trained. Some of them will have had little or no experience in industry when they begin their training, but a few of them who will take up more senior posts at Durgapur have had a number of years of experience in management.

The Durgapur steelworks, in common with the Rourkela works, which are being built with the help of German consultants, and the Bilhai plant, constructed from Russian equipment and erected with the assistance of Soviet engineers and technicians, is designed to produce initially 1 million ingot tons of steel a year. This target of 3 million tons from the three works is expected to be reached by 1961. Training schemes for Indian technicians similar to that put in hand in this country have also been initiated in Germany and Russia.

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Investing in Oil

No one in the oil business can allow himself to be influenced by what is happening now or likely to happen in two years' time. Their vistas are 10 to 20 years ahead and no decision can sensibly be taken to-day unless it is related to—at the very least—the date on which it can be implemented. For most investment items—whether the construction of a refinery, the ordering of a tanker or the expansion of an oil field—the gestation period of a decision is at least three years and often longer. This is a factor in this highly (and increasingly) specialised business which is only too often ignored both by the suppliers of the equipment and by those who sustain the latter's ability to supply good equipment with their investment.

The plans published last week by the international consortium, who own the capital of two companies operating the property of the former Anglo-Iranian Oil Company, are typical of those which have to be made irrespective of such things as rising political tension in the Middle East or slackening demand for oil. A total expenditure of £50 million has been agreed, of which £19 million is earmarked for the development of facilities to handle increased production from the Gach Saran field in southern Persia. This will include the building of roads, air strips, houses and public buildings. The main items, however, will be a major new pipeline from Gach Saran to the coast and a new loading port equipped to handle the largest tankers now being built. The budget also provides for a big increase in the output of the Agha Jari oilfield and the construction of a pipeline to Bandar Mashur, where more jetties are being built.

This type of expenditure cannot pay for itself for a decade or more, and the oil companies realise this very well. It may be that if in the next three to four years the rising trend in oil consumption ceases to climb at the rate anticipated, there will be a change of policy. There has been a slowing down in the growth of demand, despite the remarkable recovery since Suez. Yet the need for power, argue the companies, is increasing and will continue to increase irrespective of the wishes of men. This theory of the unshakeable momentum is well backed by experience. It cannot be affected by setbacks from time to time, even if these were as major as in the early 1930s.

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Consortium in Cuba

The industrial consortium is a very useful device when large contracts involving many different kinds of equipment have to be fulfilled. It brings together companies from the start who are able to understand the requirements under the contract where otherwise complicated subcontracting arrangements might have to be entered into at a later date. It has also the advantage that financial strength can be reinforced and extensive management overheads can be spread over more than one concern. There are of course disadvantages, for usually these marriages of convenience, like those of another kind, have more complications and have to be endured for longer than might have been originally intended.

Four British companies, it was announced recently, have formed a consortium to build a shipyard in Cuba along with 25 ships for carrying bulk commodities and general cargo. The four concerns are Higgs and Hill Limited, James Burness and Sons Limited, the Brush Group Limited, and Brian Colquhoun and Partners. The arrangement has to date gone as far as a declaration of common purpose with two Latin American banks for contracts estimated to be worth £30 million. Details of the scheme have not yet been settled but it includes the principal machinery and auxiliary engine room equipment for the ships, which will be about 5,000 tons deadweight each. There is a possibility of the group also receiving large orders for electrical equipment and a power station for a shipyard.

Not the least interesting feature of the yard is that it is in Cuba. For a long time this part of the Caribbean has been considered as an extension of the United States domestic market. It is to be hoped that this agreement will be the first of other large contracts in the West Indies.

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Perks for Everyone

In these days of high taxation, concessions, favours and special inducements are the order of the day. The favours extended by companies to directors and top management in the way of cars, expense allowances and housing accommodation are well known and have, with a good deal of exaggeration, provided a certain amount of political capital for those who want to use it. It is not perhaps generally appreciated that payments of one kind and another which do not attract tax are now common throughout the industrial hierarchy.

It is possible now for a clerk in the office or an operative on the shop floor of many companies to receive quite an impressive list of favours which cost the company money. The biggest of all is, of course, the pension scheme where all or most of the contribution is paid by the employer. Another considerable advantage for some employees is the provision of housing at attractive rents with equally attractive schemes in some cases for acquiring a property over a period of years. Many operatives have subsidised canteen meals and meal vouchers are fashionable in offices and factories alike. It is now possible for overalls to be cleaned and repaired on favourable tax terms. The latest plan of this kind put out by Sketchley Cleaners and Dyers offers a scheme in certain industrial areas by which operatives' overalls are provided, cleaned, repaired and replaced by a continuous van service. Whether the employer or the employee bears the cost, they can claim an expense allowance for tax purposes.

When petrol prices were raised substantially in France earlier this year, except for certain categories with priority, M. Mendes-France is reported to have said with cynical Gallic wit that there would be only two categories to consider—those with priority and fools. "Perks" may not yet have created the same air of cynicism in this country but we are heading that way.

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Rationalisation or Nationalisation?

The Government's courage in relying entirely in the near future on the guided missile for defence purposes cannot be disputed. The validity of the decision has, however, been doubted in several quarters, particularly as regards the decision not to develop a supersonic bomber. Whatever the truth may be—and discussion on any other than highly technical grounds is both profitless and dangerous—there can be no doubt as to its serious impact on the aircraft industry.

In a speech last week to the Air League of the British Empire, Lord Weeks commented at length both on the decision itself and on its consequences for the aircraft industry. In fact, he said that the White Paper has given the aircraft industry a "signpost along a very desolate road." The aircraft industry cannot exist in a competitive world without adequate funds being allocated for research and development and without the backing of research for military projects it is hard to see where these funds are to come from.

Lord Weeks put forward three possibilities for the aircraft industry. He felt that the first and proper course should be amalgamation involving the grouping or absorption of some of the smaller units by the stronger companies. The second alternative put forward was the combination of companies retaining their individual identity for the purpose of a single project. This, he felt, was a step in the right direction, but could not be the ultimate goal. The third alternative—which, in his opinion, would be a "most ghastly solution"—was nationalisation. It seems clear, however, that he felt that unless one of the other two alternatives were adopted, nationalisation would certainly follow.

At the same time, the industry could not achieve success entirely by its own efforts. Transport Command should be built up not only as an essential part of the defence system but also as a means of providing Government support for British aviation.

Engineering at Home

KEEPING WARM WITH A COOL HEAD

Some 2,000 L.C.C. flats are being built with electric floor warming. Disclosing this to a recent Institute of Housing Conference, Mr. R. J. Allerton—he is a director of housing to the London County Council—went on to claim cleanliness, efficiency and economy for this form of heating. He said that the difficulty of providing open fires in tall blocks of flats made it essential to consider other types of heating. Hot water central heating gave better results than an open fire; but it was expensive, and the tenant had little control over the amount he spent. In the new flats, tenants can control the heat to suit their comfort and their pockets.

The Electrical Development Association featured floor warming on their stand in the exhibition at the National Housing and Town Planning Conference held in Harrogate recently. One section of the stand was given over to a display of methods and materials used in electric floor warming schemes for houses and flats. Four different systems were shown.

Mr. J. W. Moule and Mr. W. M. Stevenson—both of the South of Scotland Electricity Board—describe this type of heating in a paper "Electrical Floor Warming." The paper is published in the *Proceedings of the Institution of Electrical Engineers*, part A, October, 1957.

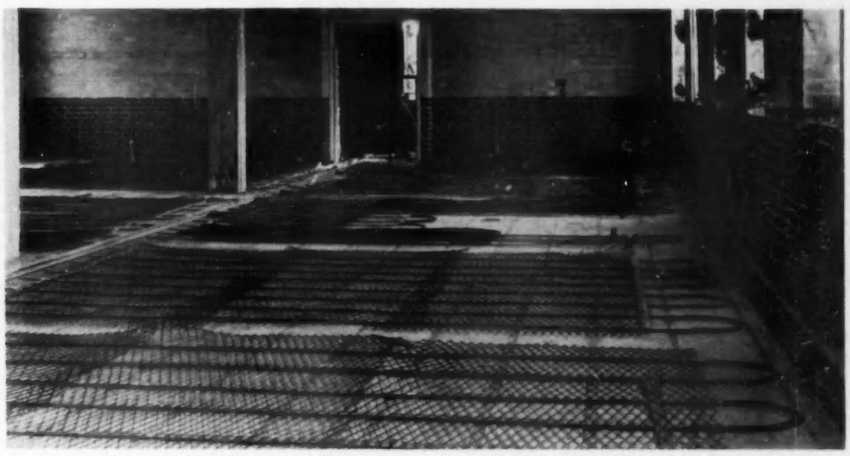

Fig. 1 A floor warming system placed in position before the pouring of the concrete screed.

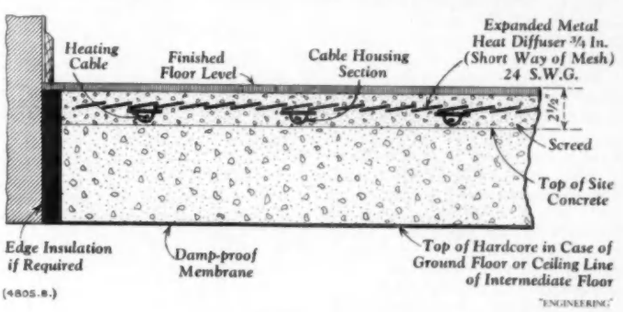
Heating Cable
Finished Floor Level
Cable Housing Section
Expanded Metal Heat Diffuser ¾ In. (Short Way of Mesh) 24 S.W.G.
2½
Screed
Top of Site Concrete
Edge Insulation if Required
Damp-proof Membrane
Top of Hardcore in Case of Ground Floor or Ceiling Line of Intermediate Floor
(4805.8.)
"ENGINEERING"

Fig. 2 The special section of the cable housing increases the heat transfer and in conjunction with the expanded metal diffuser produces an even temperature distribution across the floor surface.

Floor warming gives a uniform distribution of warmth throughout the floor area, and produces the "warm feet with a cool head" effect. The authors remark that a critical comparison of space-heating systems involves consideration of physiological and psychological factors. The air temperature by itself may not give a reliable guidance to the standard of comfort in a building. Other factors such as radiation, air velocity and humidity also have significant effects. In their opinion, two points are particularly important: (1) warmth should be transmitted to the human body mainly by radiation from uniformly warm surroundings; (2) air movements should be minimised.

Convection heating systems are condemned as wasteful and unsatisfactory: wasteful because the air temperature has to be raised to values higher than would be necessary if the right amount of radiant heat were present; unsatisfactory because such systems give excessive air movement and temperatures that are higher at the ceiling than at the floor. Experience in the south of Scotland suggests that a floor warming system working with an air temperature of 61 deg. F. at 4 ft. 6 in. above the floor provides comfort equivalent to a convection system with an air temperature of 65 deg. F. at the same height.

In electrical floor warming systems, the building structure acts as a heat storage medium. This allows the electrical load of the heating system to be switched on in the off-peak hours and off in the peak hours. The system thus improves the load factor. However, it is essential that the building does have sufficient thermal storage. And good thermal insulation of the building is highly desirable. Further insulation is required to prevent loss of heat from the edges and underside of the floor. Various materials are available to do this job; usually a thickness of 1 in. is required.

The Kirkaldy multi-storey flats provide an example of the system in practice. They are built without fireplaces or gas supplies. Electric floor warming is installed in the main living room and hall of each flat. The floor warming and a 3 kW electric water heater get their supply at an off-peak tariff. A 2 kW "coal effect" fire is provided to afford a focal point for each living room and to give supplementary heating in cold weather. This fire is connected to the normal supply.

For 10*s.* 9½*d.* a week, the tenants of two-apartment flats obtained all their space heating, water heating, cooking and lighting and other fuel services for the year. Tenants of three-apartment flats have to pay 14*s.* 3½*d.* a week. Entire satisfaction with the system has been expressed by the tenants.

A warmed floor at a constant surface temperature is to some extent self-regulating. On a mild day when internal temperatures rise, the rate of emission of heat from the floor is automatically reduced. On the other hand, if an extremely cold period should occur, the floor will emit heat at an increased rate. A thermocouple holds the floor temperature at 73 deg. F.—higher temperatures cause discomfort to the feet.

There are two main categories of electrical floor warming installation. First, that in which a heating cable or wire is buried solidly in the concrete floor. Second, that in which circular or D-shaped metal housings are built into the concrete floor in a way that allows the cables to be drawn into them when the floor is finished.

In the floor warming system produced by Panelec (Great Britain) Limited, 21 Bloomsbury-street, London, W.C.1, the heating cables are housed in metal pipes. By their special section, seen in Fig. 2, the pipes—with a layer of expanded metal or lathing under the floor—transmit the heat evenly to the floor surface. The runs of housing section are held rigidly together by jig bars, which also serve to keep the metallic components in good thermal and electrical contact. Positive earthing is provided. Fig. 1 shows a typical system before screed laying. A lead-covered cable is generally used, consisting of twin conductors with heat and moisture resistant insulation. The conductors at the far end of the cable are connected together during manufacture. This enables connection to the supply to be made at one end only. The makers say that the supply of equipment and the installation generally cost between 4*s.* and 5*s.* 6*d.* per sq. ft. of area heated.

B.B.C. TELEVISION EXPERIMENTS

Television signals are being broadcast by the B.B.C. at a frequency of 654·25 Mc/s. The wavelength of the transmission is thus about ½ metre and the appropriate receiving aerials measure about a fifth of the size of those used to receive the present I.T.A. programme. The transmissions form the final stage of a programme to find out whether the ultra-high-frequency bands (Bands IV and V) can be used for television. If these frequencies eventually come into general use, some reduction in the amount of hardware that now bristles on rooftops might be expected.

For several hours a day the new signal is being radiated from the top of the Crystal Palace aerial tower. The pictures will be the same as those broadcast by the Band I transmitter. Although the 405-line standard will be used at first, experiments will be made later with pictures on 625 lines—as used on the Continent. For the latter tests the programme will usually be different from that radiated by the Band I transmitter.

The B.B.C., the I.T.A., the radio industry, the Post Office, and the D.S.I.R. are organising comprehensive studies of the received picture. Receivers of different types will be used. It is hoped that the tests will throw light on the problems that would be encountered were it decided to provide television services in the ultra-high-frequency bands. Also the effects of a change from United Kingdom television standards to those of the Continent will be studied. The B.B.C. say that they have no intention of making any change in the 405-line standard used for television in Band I.

Marketing

FOR COMPETITION'S SAKE

The duplication of effort involved when firms tender for the same project has always been a sore point with the people concerned. Many commendable efforts have been made by trade associations to reduce this wasted effort. Nonetheless, these well-intentioned efforts have all too frequently been thwarted by equally well-intentioned people who have seen in common tendering a threat to the whole principle of tendering. Now a new appeal has been made for some thought to be given to the problem of eliminating the continual wastage of time and effort by engineers and estimators.

Sir George Nelson has pleaded for an objective study of what he described in his presidential address to the Institution of Mechanical Engineers as "one of the greatest problems with regard to the efficient utilisation of technical personnel. All my life," he said, "it has been a nightmare to me that firms such as mine are constantly submitting tenders which may cost as much as £20,000 to £30,000 to assemble, of which only 10 per cent. result in orders. The waste involved in the 90 per cent. of unsuccessful tenders throughout the whole of our great engineering industry is colossal. It is bad enough in terms of money but far worse than this is the effect in terms of technical manpower." Sir George went on to point out that the elimination of this waste was beset with political difficulties, but that it was largely a matter of establishing confidence between the purchaser and the supplier. Towards the end of a long and detailed review of all the factors in the efficient utilisation of the country's technical resources, Sir George concluded that the problem of "excessive competition for the sake of competition" was "the greatest factor in the waste of technical manpower."

There is a very strong case for having the problem investigated in an unprejudiced atmosphere, as Sir George suggests. Among the many things that could emerge from such an inquiry would be how far competitive tendering is in fact competitive window dressing and not competition. Most plant users are rightly insistent on having put to them by several suppliers schemes to meet their special requirements—not only to avoid paying more than they need but to get the benefit from a number of different outlooks and skills. It is not only, therefore, price competition that is involved but competition in technical excellence. On the other hand, the cost of this should be clearly defined, so that the purchaser of the plant, machine or installation knows how much it will cost him to get competitive tenders from several firms. At present, the cost to him is nil but the cost to the nation is fabulous, for throughout engineering it is rare that a firm receives in orders much more than 25 per cent. of the tenders submitted. Yet all are short of estimators and good ones are at a premium. One result is low quality tendering, which in turn involves technical manpower at the other end. But more than that, poor tendering loses orders abroad. The cost of this to the country is probably much greater than the cost of the wasted effort in competitive tendering at home. It is a major problem, and most urgent.

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The Progressive Exporter

An article in the G.E.C. Export Guide for October reviews changes in the pattern of British exports since the end of the war and attempts to draw conclusions. "New exports" are presented in tabular form showing the rate of growth, which in some cases will surprise even those who are in constant touch with export matters. Among the products not in the list in 1948, but now valued at several millions of pounds a year, are antibiotics and other drugs, prefabricated buildings, Diesel locomotives, combine harvesters, floor polishers; among those which have made the greatest headway are telecommunication equipment, including radar.

Among the criticisms of the British export performance contained in the article is that relatively few firms are responsible for the country's achievements: "if their performance were matched by a large number, Britain would not be falling behind in the race for export markets." One criticism which is not made, though perhaps it is implied, is that Britain relies still to a very marked extent on traditional exports which have for years provided our foreign currency bread and butter, such as textiles, motor vehicles and other consumer goods. In short, we depend far too much on what is increasingly made in our export markets, albeit under heavy protective cover.

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Selling by Film

The part which can be played by the industrial film in influencing the potential customers has been the subject of a lively debate in recent weeks. There is a growing number of salesmen who have considerable faith in this method. Like most pioneers in the cause of a technique they have tended to overstate their case. Similarly, perhaps, have the supporters of closed-circuit television for demonstration of certain equipment, factory tours, advertising, parades and the like. On the other hand there is little doubt that more and more of this country's engineers view industrial films showing their suppliers' factories or the equipment they require being used elsewhere. With suitable commentaries this is much more effective than, say, the printing of photographs showing installations (a method used extensively by the German engineering industry).

In a letter to the *Financial Times* last month, Mr. B. Charles Dean, managing director of Hartley-Ward Films, points out that some caution is needed in the expectation of spectacular results overseas. Effective distribution involves close co-operation with the United Kingdom Government agencies "whose services and machinery are indispensable if this is to be achieved." There is need for effective planning and for careful study of a market before a film is shown. Like most sales promotion methods, it should be part of a campaign, with good support and follow-up, if it is not to result in wasted effort.

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Selling by Competition

So much that is novel in sales promotion and publicity has been attempted by F. Perkins since the war that one is tempted to take their efforts for granted and not look too closely into them. But their latest is "different" enough in the field of capital goods to be almost startling. They have organised competitions, open to power operators, "irrespective of whether or not they are Perkins engine owners," for which engines will be given as prizes. The winners will be the four operators who submit "the best slogans for Perkins Diesel engines in the vehicle, industrial, agricultural and marine sections."

This is a little more than the advertising stunts of newspapers offering motor cars or insurance policies or television sets as prizes. There is the same emphasis on slogans and the listing of qualities. For example, why Diesel engines are considered preferable to any other type of engine and what are the advantages of Perkins' engines which appeal most. Some information will therefore be forthcoming from the section of people—the operators—most difficult to reach effectively by market research techniques suitable for a technical product.

This is Perkins' second attempt; when they organised a competition in 1951 with a tractor as first prize more than 50,000 entries were received. It is perhaps a cheap way of influencing the choice of make, perhaps also a method of obtaining information on technical features. On the whole, however, it falls more into the category of sales gimmicks than in that of serious market research.

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Seeking the Cash

Recent downward movements in commodity prices have sent the terms of trade soaring in favour of the United Kingdom, but it would be wrong to interpret this as a net gain. It has meant an increasing degree of austerity for the primary producing countries which are our best customers. India's considerable difficulty in securing the necessary capital to carry out her industrial development programme is an example of the effect on all major suppliers of raw materials if the present trend continues. Because of the serious deterioration in her trading balance and the running down of foreign currency reserves, India is being forced to continue restrictions on many imported goods for at least another six months. Her representatives have failed to get the cash they need in the United States or in this country. Few people realise that the falls in raw material prices that have taken place in recent months have been equivalent to cuts of many millions of pounds in the financial assistance given to these countries.

We are all familiar with the effect on Australian purchasing of the dramatic fall in wool prices two years ago. We must now watch the effect of the falls in the prices of tin, copper, wood pulp, etc., on Malaya, Canada, Scandinavia, South Africa and many other of our good markets. In this lies the greatest risk of a serious depression.

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China Trade

The arrival in this country of a large technical and diplomatic mission from the Republic of China is the logical result of our breaking away from the total embargo policy pursued by the United States. Dr. Chi Chao-ting, who is vice-chairman and general secretary of the China Committee for the Promotion of International Trade, is leading the 18 man team, most of whom come from industrial research establishments. There are representatives from the motor industry, shipbuilding, both non-ferrous and ferrous metals, power machinery, steel plant, wires and cables, electronics and other specialised fields. It is one of the most high powered technical missions to visit this country since the war.

The Chinese are here to visit British factories in their field and to see for themselves the progress that has taken place in the past decade or so. Most are very well informed on technical developments and all those to whom we talked read widely the leading British technical journals. A disappointing feature of the reception given to the Mission by the British Council for the Promotion of International Trade was the absence of many leading figures in British engineering. For example, in the field of non-ferrous metals, there were some notable absentees. More were there from the machinery fields, but the fact remains that only 86 executives from industrial firms attended.

Only two weeks before the mission arrived Vickers sent five very senior men to China "to discuss the re-opening of trade relationships." This shows a greater sense of opportunity than has so far been displayed by the majority of British engineering firms.

Research and Development

REVISION OF FUEL RESEARCH

A new Fuel Research station is to be built at Stevenage. Work on the site has begun and the station should be completed in 1959. Accommodation will be provided for a non-industrial staff of about 220 and an industrial staff of about 120. The estimated cost is of the order of £750,000.

It was decided that it would be uneconomic to spend more money on the present Fuel Research station at Greenwich. This decision led to a careful review of the present needs for research in this field. In consequence, the programme for the new station will differ markedly from that of the old one. Only two of the researches now being undertaken at Greenwich will be transferred to the new station. One is the study of the synthesis of oils and chemicals from carbon monoxide and hydrogen; the other is work on atmospheric pollution and its prevention. It is planned that a full scientific service in the latter study will be provided for the Ministry of Housing and Local Government to assist administrative decisions arising under Clean Air Act regulations.

The state of fuel research in Great Britain has changed a great deal since the Fuel Research station was set up in 1917. At that time there was a need to cover the whole field of research on solid, liquid, and gaseous fuels. Since then, the work of the station in opening up the field and pointing the way for further work has led to the growth of other organisations for research on fuels. Many have taken over branches of work which in the past had been done by the Fuel Research station.

The work at the new station will not be confined to fuel research but will include any other selected investigations requiring staff and equipment, including intermediate scale facilities, of the kind installed for fuel research. An example of this sort of work is provided by mineral-processing research. The increasing demand for metals has given rise to the need to examine new methods for the treatment of low grade complex ores.

HOLDING TWO DEUCES

No one will deny the importance of mathematics to engineering. The last two decades have seen an enormous increase in its scope and influence. Parallel with the increase has been the evolution of computing aids, and among these the electronic digital computer stands supreme. The Royal Aircraft Establishment, Farnborough, provides an example of the growth of a computing service.

Its Mathematical Services Department was formed nearly ten years ago to provide a mathematical and computing service for the establishment. Between 1950 and 1955 the department made considerable use of the ACE pilot model computer at the National Physical Laboratory. In 1955, DEUCE, an engineered version of the ACE, was installed at Farnborough. By 1956 the load of work on the first machine had increased so much that a second machine was acquired. Now, in addition to these two large machines, the Mathematical Services Department has a Hollerith punched-card installation and a number of small computing instruments of both analogue and digital type. Other computers—notably TRIDAC, the large analogue installation—are in operation in other departments.

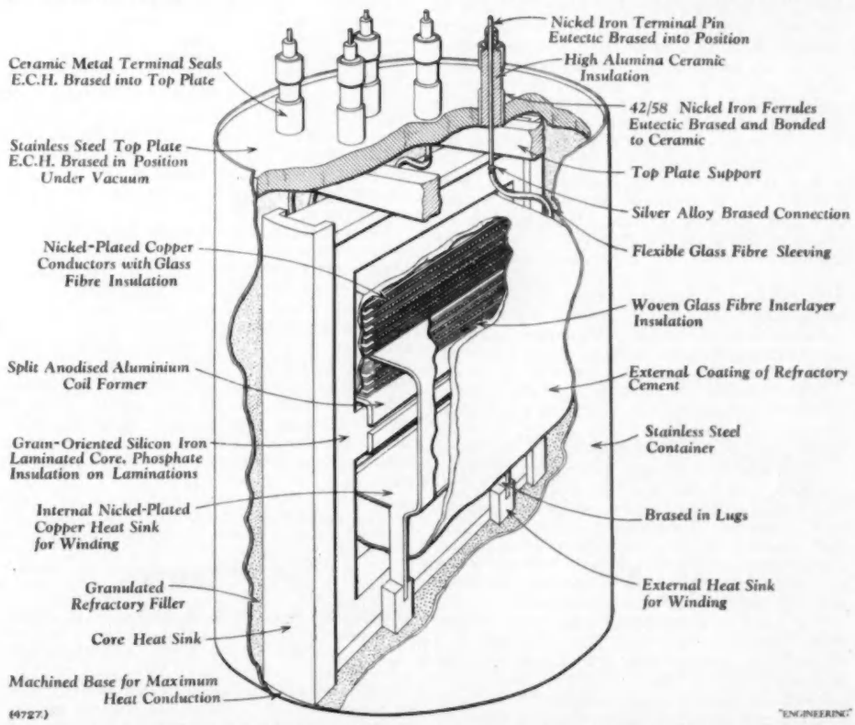
DEUCE is made by the English Electric Company Limited, Kidsgrove, Stoke-on-Trent, Staffordshire. Up to the end of September, 1957, a total of 6,240 hours of "good computing time" had been achieved with the Farnborough machines. This works out to an average of about 46 hours per week per machine. The machines normally operate until 10 p.m. on weekdays, with occasional all-night or weekend workings on jobs of special urgency. Routine testing and servicing take up about two hours each day per machine. Excluding these two hours, the overall operational efficiency—the ratio of "good" time to the total "switched on" time—is just over 90 per cent. for the younger machine, and about 85 per cent. for the other.

Evaluation of experimental results takes up about one-tenth of the total computing time. The remainder is given over to theoretical investigations; typical of these is aerodynamic wing design. In the treatment of experimental data the department has made considerable progress since it was founded. In a research establishment problems and requirements are constantly changing and flexibility is a prime consideration. The process now in operation may be divided into three stages: transcribing the raw data on to Hollerith punched cards for input to DEUCE; computing on DEUCE; displaying the results in a convenient visual form. Each stage is made as automatic as possible but manual operations are allowed between stages for flexibility.

The treatment of wind tunnel data gives an example of the system in operation. Readings of tunnel measuring instruments—strain gauges, manometers, etc.—are converted into mechanical shaft rotations and then, by means of shaft digitisers, into digital electrical signals. A number of such outputs are scanned and the output signals are fed to a machine which decodes them on to punched cards. Up to this point the process is automatic. The punched cards are then carried by hand to DEUCE for computation.

HOT TRANSFORMERS

An increasing proportion of service electronic equipment has to work at high ambient temperatures. But, at the same time, size and weight have to be reduced to a minimum. Power transformers are often an essential part of such equipment and, like other heat dissipating components, can usually be reduced in size and weight if a higher internal temperature rise can be tolerated.


Nickel Iron Terminal Pin Eutectic Brased into Position
Ceramic Metal Terminal Seals E.C.H. Brased into Top Plate
High Alumina Ceramic Insulation
42/58 Nickel Iron Ferrules Eutectic Brased and Bonded to Ceramic
Stainless Steel Top Plate E.C.H. Brased in Position Under Vacuum
Top Plate Support
Silver Alloy Brased Connection
Nickel-Plated Copper Conductors with Glass Fibre Insulation
Flexible Glass Fibre Sleeving
Woven Glass Fibre Interlayer Insulation
Split Anodised Aluminium Coil Former
External Coating of Refractory Cement
Grain-Oriented Silicon Iron Laminated Core, Phosphate Insulation on Laminations
Stainless Steel Container
Internal Nickel-Plated Copper Heat Sink for Winding
Brased in Lugs
Granulated Refractory Filler
External Heat Sink for Winding
Core Heat Sink
Machined Base for Maximum Heat Conduction
(4727)
"ENGINEERING"

The transformer designed to operate at 500 deg. C. uses glass-insulated wire interleaved with glass cloth. The case is evacuated and is about 2 in. in diameter.

The magnetic properties of the iron core limit the maximum permissible temperature of any part of a transformer to about 500 deg. C. At this temperature organic insulating materials decompose, copper wire corrodes in air, no satisfactory liquid coolant is available, and jointing with soft solder is inadmissible.

Experimental transformers, of two different types of construction, for operation at 500 deg. C. were on display at the International Symposium on Electronic Components recently held at the Royal Radar Establishment, Malvern. One transformer was designed and made at the Establishment. The other was developed for the Establishment by the Plessey Company, Limited, Ilford, Essex.

The R.R.E. transformer is wound with glass-insulated nickel-plated copper wire, interleaved with glass cloth, on a split metal coil-former. The core is of grain-oriented silicon-steel laminations. An evacuated stainless steel case, carrying metal-ceramic terminal seals, encloses the assembly. Leads are brazed to the seals. To aid heat dissipation by conduction to the case, copper plates are embedded in the winding assembly and the interspace is packed with a granulated refractory material. A diagram showing the construction is on the left. The nominal rating of the transformer is 100 VA at 1,600 c/s.

The Plessey transformer is of open construction. The coils are wound in sections, on a circular porcelain bobbin, with glass-fibre covered nickel-plated copper wire. The wire is further treated with vitreous enamel during winding and the winding assembly afterwards subjected to a slow baking process. The leads are brazed to nickel terminals mounted on the bobbin. Made up of silicon steel laminations, the core is of cruciform section. The transformer was shown operating at an ambient temperature of 500 deg. C. Its nominal rating is 50 VA at 50 c/s.

Book Reviews

MIDDLE EAST REALITIES

The Economic Development of Jordan. Report of a Mission Organised by the International Bank for Reconstruction and Development. *The John Hopkins Press, Baltimore* 18, *Maryland, U.S.A.* (7.50 dols.)

Much attention has been focused in recent years on the Hashemite Kingdom of Jordan. This timely report, made at the request of the Government of Jordan by a mission organised by the International Bank for Reconstruction and Development, refers to a survey of the country made in 1955; hence its recommended 10-year plan is already two years old.

The mission's eight members were recruited by the Bank from nationals of Australia, Belgium, France, Greece, the Netherlands, South Africa, the United Kingdom and the United States. Their task was to review Jordan's economic potentialities and to recommend a long-term development programme for the country. The mission travelled extensively in Jordan from March to July, 1955, and their report is a thorough and most valuable survey.

A brief description of present day Jordan is perhaps appropriate here. Jordan became an independent state in 1946, on the termination of the British Mandate, and its present situation dates only from 1950. Its area is about 30,000 square miles and its population may be estimated at 1,400,000. The land area is about that of Ireland, and about half that of neighbouring Syria. Much of the land is unusable however, because of a very low rainfall—80 per cent. of the country has a rainfall of less than 7·9 in.—and because its remoteness from available water precludes irrigation. Jordan is a country of deficiencies: no coal, no oil, no metallic minerals. It has supplies of phosphate and potash; but it is predominantly an agricultural country.

The influx of very large numbers (estimated at half a million) of Arabs from Palestine, following the war with Israel, for whom no work exists or can readily be found, provides an almost insoluble problem. Jordan's dependence on foreign aid, formerly mainly British and now jointly British and American, has always been heavy and runs at considerably more than half of the total Government revenue.

The plan recommended by the mission, and presumably now to some extent in operation, comprises development schemes which require an increase in foreign aid for the first five years and a tapering off of this aid in the second five years. The total expenditure proposed is within the present scale of financial aid—which consists of an interest-free development loan of £2·25 million from the United Kingdom, and development assistance of £1·8 million from the United States, totalling £4·05 million. In the plan, the maximum financing requirement falls in 1957-58 and is given as £4·34 million; the amounts then drop gradually to £0·685 million in 1964-65. Significantly, in the light of recent developments, the estimates make no provision for foreign aid towards defence costs, which are at present met by special foreign grants; nor do the estimates include any possible interest charges in respect of the Jordan Government's indebtedness.

Agricultural development is given first priority because of low rural productivity. Unless it can be raised, there is no hope of improving the living conditions of a large section of the population. Emphasis is given to rain-fed rather than irrigated crops. As the area planted cannot be much extended, the yield must be increased; and this depends largely upon agricultural education and research. Detailed proposals are made for the provision of a farm institute and for necessary developments within the Ministry of Agriculture. Further financial aid, over and above the existing village-loans scheme, will be required for farmers and cultivators, and the report enlarges upon this. From all the measures considered, it is estimated that production could be increased by 38 per cent. in ten years. Against this is the sobering fact that the natural increase in the population is about 3 per cent. a year.

The mission recommends a revival of Jordan's potash industry and a major expansion of phosphate mining. Both developments require outside technical advisers and, almost certainly, foreign capital.

The development of industry is restricted by the limited supply of raw materials available, the high cost of power and the very small home market. Proposals are made for developing all aspects of the olive industry, for food processing and for pottery. Guarded recommendations are made for the establishment of a small spinning and weaving mill (5,000 to 10,000 spindles and 100 to 200 looms), and a petroleum refinery capable of dealing with 200,000 tons by 1960.

Further recommendations relate to power, transport, roads, communications, housing and tourism. Jordan's only port is distant Aqaba, in the far south on the Red Sea, where the volume of traffic is expected to rise so much as to make the existing facilities inadequate. A development programme for the port is given, calling for an expenditure of £1,450,000; the principal feature is a deep-water mineral loading berth.

Sections of the report deal with monetary institutions, foreign trade, public finance and administration. Taxing changes are suggested, revolutionary for a country such as Jordan (or, indeed, for some other Middle East countries) to reduce the dependance of the revenue upon customs and excise taxes, which in fact provide 60 per cent. of the total tax revenue. Most disturbing is the information given in the report on unemployment. The pressing refugee problem and the saving activities of U.N.R.R.A. are given much attention.

In 1955 there were in Jordan about 40,000 persons partially employed but a further 60,000 with no employment of any kind. The mission thinks that the growth in production as the result of the measures they recommend " will nevertheless result in a rise in the standards of living of those of the population who have access to land or possess industrial skills." But they also think that there will be little decrease in the number of those at present partially or wholly unemployed. By 1965 they envisage an unemployment figure of 100,000. They state without ambiguity that in the long run it is clear that Jordan's resources are inadequate to absorb both the present population and the increase that, in the absence of emigration, must be expected by 1965.

The general impression left upon the reader by this able and thorough report is one of apprehension and near despair.

A BASIS FOR FOUNDATION DESIGN

The Measurement of Soil Properties in the Triaxial Test. By ALAN W. BISHOP and D. J. HENKEL. *Edward Arnold (Publishers) Limited*, 41 *Maddox-street, London, W.*1. (70s.)

In the application of soil mechanics to engineering problems shear strength is probably the most important relevant soil property. Nearly 200 years ago Coulomb formulated his well-known law expressing the shearing resistance of cohesive soil in terms of the cohesion c and the angle of shearing resistance ϕ. Careful investigations during recent years have shown that for a given soil the quantities c and ϕ vary with the conditions of the test or of those under which the soil is loaded in the field. The principal factor in this variation is the pore pressure, which in turn depends upon the drainage during the loading and shearing processes.

Several methods for the determination of shear strength are in common use, but the triaxial compression test is generally considered to be the most useful for this purpose. It is the only method in which the stress system conforms closely to that occurring in nature, while specified drainage or non-drainage conditions can readily be simulated. It has the further advantage that, with the aid of auxiliary apparatus, accurate measurements can be made of changes in pore pressure and volume during the test.

The book by Dr. Bishop and Mr. Henkel gives a comprehensive treatment of the triaxial test and its applications. The authors have for some years made a special study of the shear strength of soils and have carried out extensive research work in the Soil Mechanics Laboratory at Imperial College, London, under the direction of Professor A. W. Skempton. They have thus had considerable practical experience with the apparatus described in their book. Many of the special devices mentioned in the text owe their origin to the authors' own ingenuity.

The book is divided into four parts, in the first of which the basic principles of strength and deformation measurement are stated, and the relations between the usual test conditions, namely, undrained, consolidated-undrained and drained, are explained. Part II deals with the apparatus, including details of the measurement of shear strength, pore pressure and volume change. Part III gives the procedure for standard tests, while in Part IV a number of special tests, designed for research work, are described. The book concludes with appendices containing data on corrections which should be applied to experimental results, an extensive bibliography and a list of British manufacturers of equipment and components.

The part dealing with so-called standard tests includes a number of test procedures which at this stage can hardly be regarded as standard. Some of these might well have been included under the heading of special tests, and more prominence given to tests such as the undrained and consolidated-undrained tests on saturated clay which are the most usual in normal testing routine. The authors have, however, in describing some of the elaborate refinements and corrections which are essential for accurate research work, indicated where such details can be ignored in routine testing.

The authors are to be congratulated on having produced not only a book which is the first comprehensive work on this important branch of soil mechanics, but also one which is very " readable " and well set out. The book is profusely illustrated, and the diagrams are large and clear. It is to be regretted that such a useful addition to soil mechanics literature could not have been offered at a more popular price. Although much of the information given is primarily for the expert, the book should be in the possession of all who use the triaxial test, whether for routine testing, teaching or advanced research.

★ ★ ★

NEW BOOKS

Metallurgical Progress—3. A third series of critical reviews reprinted from *Iron and Steel*. *Iliffe and Sons Limited, Dorset House, Stamford-street, London, S.E.*1. (6s.)

The principle of compilation of this third series of critical reviews on metallurgical progress has remained unchanged. The contributors have searched the literature for the past 30 years, often in several languages, and from their findings have produced

a reasoned survey of the current state of knowledge on their particular research subject. The articles are written in a concise, easily readable style. The present publication contains reviews on "Refractories in the Iron and Steel Industry," by Dr. Helen Towers; "Non-Destructive Testing," by Dr. J. M. McLeod; "Metallurgical Coke, 1939-1955," by Dr. J. Taylor; "Foundry Sand Practice," by Mr. W. B. Parkes; "Reducing the Phosphorus Content of Foundry Iron," by Mr. R. I. Higgins; "Iron Foundry Metal-Melting Furnaces," by Mr. Frank Dunn; and "Mechanical Properties of Flake-Graphite Cast Irons," by Mr. G. N. J. Gilbert.

Magnesium Casting Technology. By A. W. BRACE and F. A. ALLEN. *Chapman and Hall, Limited, 37 Essex-street, London, W.C.2.* (21*s.*)

The successful production of magnesium-alloy castings depends upon the careful observance of certain well-established principles, the chemical and physical properties of these materials necessitating a special foundry technique. The present work was begun by the late Mr. Frank A. Allen and has been revised and completed by his colleague, Mr. Brace. There are 11 chapters and among the subjects dealt with are: melting practice, moulding and core sands, sand castings, gravity die-casting, pressure die-casting, the heat-treatment of castings, the inspection of finished castings, surface treatments, and applications of magnesium castings.

Design in Structural Steel. By JOHN E. LOTHERS. *Longmans, Green and Company, Limited, 6 and 7 Clifford-street, London, W.1.* (56*s.*)

With this book the authors have attempted to produce a comprehensive volume covering structural steel for the student, the practising engineer and the teacher. Many of the formulae, however, are not derived by rigid argument but are quoted from other works. Stresses and techniques are to accepted American practice. A large number of worked problems are given to assist the student and to elaborate the working methods proposed by the authors. A considerable amount of space is given to the design of simple connections and details in riveted, welded and bolted steel work.

Quality Control for Plastics Engineers. Edited by LAWRENCE M. DEBING. Sponsored by the Society of Plastics Engineers Incorporated. *Reinhold Publishing Corporation, 430 Park-avenue, New York 22, N.Y.* (5 dols.); and *Chapman and Hall Limited, 37 Essex-street, London, W.C.2.* (40*s.*)

The subject of statistical quality control is developed as simply and clearly as possible in this book to enable plastics engineers, moulders and other technicians having no previous knowledge of the subject to use the basic statistical procedure to achieve high standards of performance. The present work is the first of a series of technical volumes which aim at the dissemination of technical information on plastics, and it has been organised by the Quality Control Committee of the Society of Plastics Engineers. Dr. Debing is the chairman of this Committee and the authors of the various chapters are all specialists in the field of statistical quality control.

On the Shelf

By Frank H. Smith

I have had advance notice of a forthcoming journal by Springer-Verlag entitled *Archive for Rational Mechanics and Analysis*, published by Lange and Springer, Reichpietschufer 20, Berlin W.35, Germany. It is announced as "appearing in numbers struck off as the material reaches the press" and five numbers will constitute a volume at DM96 per volume. The journal will follow a trend that is becoming increasingly popular of using more than one language, and papers will be printed either in English, French, German, Italian or (hold it!) Latin. The first number has three papers in English, two in German and one in French. The aim of the publishers is rapid publication which is an aim that will commend itself to all readers of technical literature. The title will make for pleasant confusion with the *Journal of Rational Mechanics and Analysis*.

I notice that the *Aeronautical Engineering Review* of the Institute of the Aeronautical Sciences now has under its title the words: Aircraft. Missiles. Rockets. Satellites. Spacecraft. If any one can think of any other off-the-ground body not covered by these, I shall be pleased to forward it to the I.A.S.

The truth of "birds of a feather" is, of course, exemplified in almost all associations, societies and institutions, and reference to "Whitaker's" societies and institutions section shows what a variety of birds there is. In America, I believe, it is even more the case and I have just received the 25th edition of the roster of the Aviation Writers' Association. An accompanying letter tells me that the Association has grown from a "handful" in 1938 to over 860 to-day. Such figures are, I suppose, a great consolation to the public relations officers of aircraft firms but it must mean quite an expenditure in "hand-outs" of publicity material. Two of the members are in this country—one being a United States Air Force officer.

The Superintendent of Documents, Washington, 25, U.S.A., issues subject catalogues of the various publications of the U.S.G.P.O. (Government Printing Office) similar to the Sectional Lists of our own H.M.S.O. The latest to arrive are "Industrial Workers" which is numbered PL 78 (Eighth Edition), "Aviation," PL 79 (Eighth Edition) and "Navy" PL 63 (37th Edition). These are but three of the specialist lists which number 45 and all are obtainable, gratis, from the address at the beginning of this paragraph. Some of the other subjects covered are Geology (No. 15), Labor (sic) (No. 33), Irrigation, Drainage, Water Power (No. 42), Atomic Energy and Civil Defense (No. 84) and, for those who take their T.V. seriously, Indians (No. 55). The publications themselves can be bought through H.M.S.O., thus surmounting the dollar fence.

An establishment (its own description) called RUCH which calls itself the enterprise for distribution of foreign publications in Poland is going to organise a permanent exhibition of "most interesting foreign periodicals." This strikes me as being an excellent idea, both for the Pole who contemplates subscriptions to journals in his particular field and for the publisher in this country who wishes the Pole to see what he produces.

A paper in the July-August *Journal of the Institution of Engineers, Australia*, on "The Tennyson Power Station, Brisbane" has a most useful appendix of a type that I do not remember seeing before in such a paper. It is a "Schedule of Technical Details" and lists particulars of all the machinery that has gone into the station, with the name of the manufacturer, particulars of equipment and so forth. Even the area of the site and its exact location are given.

Somewhere between 1957 and 1960, the Russians will be publishing their (five-volume) version of the late war. I mention this only to be able to inform those who are interested that they do not refer, as we do, to the Second World War. They call it the Great Patriotic War of the Soviet Union. Was it not Edith Cavell who said "Patriotism is not enough?"

The October *Scientific Film Review*, the journal of the Scientific Film Association, 164 Shaftesbury-avenue, London, W.C.2, price 3*s.* 6*d.*, is a special issue and includes a filmic bibliography of 135 items on work study. The titles are gathered from all over the world and range from films of specific tasks, such as assembling gas-cooker taps (trust the French to have something gastronomic—no pun meant) to general studies of time and motion experiment. Each title is accompanied by an outline of the film so that there is no danger of an engine manufacturer, for instance, borrowing "Shaft Survey" only to find that it is a Coal Board effort, or of a sempstress borrowing "Handling a Flour Sack" only to find that it really is a sack and not a *haute couture* creation.

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Man-Made Fibres and Engineers. COURTAULDS LTD., 16 St. Martin's-le-grand, London, E.C.1. The scope and prospects of engineering in all its grades, in connection with building and civil engineering, plant design and layout, the installation and maintenance of equipment and machinery, electrical engineering, and textile-production engineering in all its forms. These are outlined for the benefit of prospective entrants in a publication entitled "Engineering in Courtaulds."

High-Temperature Cements. THE MORGAN CRUCIBLE CO. LTD., Battersea Church-road, London, S.W.11. Originally developed by Bristol Aero-Engines Ltd., Brimor high-temperature cements are claimed to give good bonding to metals and ceramics, to possess good mechanical strength, good resistance to thermal shock and good electrical insulation properties. All the above are retained at temperatures of up to about 750 deg. C. Technical publication.

Sprayed Asbestos Insulation. SPRAYED INSULATIONS LTD., 20-30 Thomas-road, Burdett-road, London, E.14. "Silbestos" sprayed asbestos insulation for roofs and other surfaces is produced by blowing on specially prepared asbestos fibres in atomised water. It is claimed to seal effectively gaps at gutters and ridges and to have also a sound absorption factor of 60 per cent. at 500 cycles per second. Illustrated leaflet.

Steel Founding. K. & L. STEELFOUNDERS AND ENGINEERS LTD., Letchworth, Hertfordshire. Description of the production of steel castings by the firm, including design methods, pattern making, core making, moulding, melting, chemical analysis, tapping, pouring, dressing, heat treatment, non-destructive testing, physical testing, inspection and machining. Brochure entitled "The Steelfounder's Craft."

Magnetic Iron. HELLEFORS BRUKS A/B, Hellefors, Sweden; application for prices and particulars to be made to: ERNST B. WESTMAN LTD., 39 Lombard-street, London, E.C.3, and 22 High-street, Sheffield. Hellefors "Remko" magnetic iron is a soft pure material having a uniform composition and properties. It has a low coercive force and high induction, and can be fabricated by pressing and bending. Descriptive booklet of properties.

Vinyl Compounds and Synthetic Rubbers. BRITISH GEON LTD., Devonshire House, Piccadilly, London, W.1. Polyvinyl materials and their properties, processing conditions and applications; and Hycar nitrile rubbers and their properties, compounding, mixing, moulding and extrusion. Technical booklets (Vinyl Compounds No. G.5; Nitrile Rubbers No. H.1.

Plastics Pipe Fittings. HORWITCH SMITH & CO. LTD., Pensnett, Brierley Hill, Staffordshire. Oxythene injection moulded polyvinyl chloride tube and pipe fittings, available in British Standard Pipe threads, for use with acid pumps, fume-absorption equipment, acid-pickling plant and other installations where high chemical resistance is essential. Leaflet bulletin of sizes.

Electroplate. ALBRIGHT AND WILSON (MFG) LTD., 1 Knightsbridge-green, London, S.W.1. Kanigen corrosion-resisting electroplate is a nickel-phosphorous alloy containing about 8 per cent. of phosphorus. The deposit is hard and wear-resistant and the throwing power of the electrolyte is claimed to be "infinite." Illustrated leaflet.

Oil in Heat-Transfer Systems. MOBIL OIL CO. LTD., Caxton House, London, S.W.1. Oil possesses advantages for use as a heat-transfer material in indirect-heating systems in industry. Technical bulletin giving brief description of installations and the results achieved.

Metal Degreasing. IMPERIAL CHEMICAL INDUSTRIES LTD., Imperial Chemical House, London, S.W.1. The various methods now adopted for metal degreasing by trichlorethylene. The plants used and their installation and maintenance. General booklet.

Asbestos. THE CAPE ASBESTOS CO. LTD., 114 & 116 Park-street, London, W.1. Caposite Amosite asbestos moulded thermal-insulation materials in the form of blocks and pipe sections, also pure asbestos rope lagging and insulating and finishing cement compositions. Illustrated brochure.

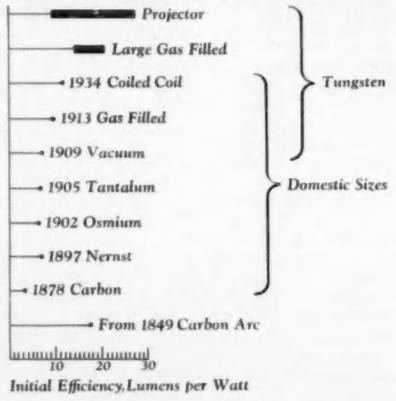
Design

MANAGEMENT, LIGHTING AND ENGINEERS

CURRENT DESIGN AND PRACTICE

By W. Robinson,
B.SC., A.M.I.E.E., F.I.E.S.

The development of electric lamps from the first carbon-filament lamp of Edison to the high-efficiency lamps of the present day is one of the most important achievements of the Twentieth Century and represents a major contribution to our present pattern and standard of living. Fig. 6 illustrates developments since the carbon-arc lamp. This rapid development has created its own problems, however, for the early lighting technique, which consisted mainly of substituting electric lamps for the existing candles, oil lamps or gas lamps, was only adequate so long as the electric lamp retained similar lighting characteristics. From the introduction of the drawn-wire tungsten filament, however, in 1911, the higher brightness of the lamps introduced a new element of discomfort and protection from "glare" became a design factor in lighting.



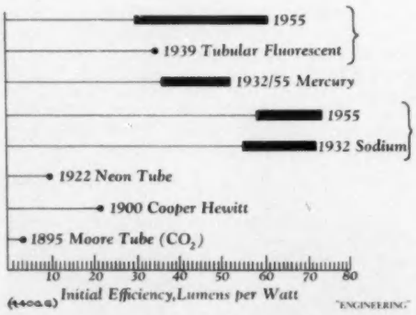
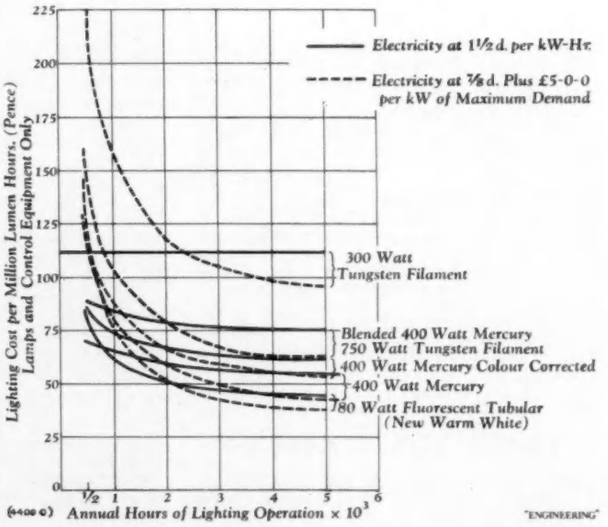


Fig. 6 (left) Improvements in lamp efficiency since the early carbon arc. Efficiencies shown for early filament lamps (upper diagram) are those for normal domestic sizes.

Fig. 7 (right) The curves indicate how annual cost of providing the unit quantity of light (in this case a million lumen-hours) varies according to the conditions of use and the type of lamp installed.



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Furthermore, as the unit cost of electricity steadily decreased with the expansion of electricity generation and usage it became economically possible to use higher wattages which favoured the use of "general" lighting, i.e., lighting by lamps arranged more or less symmetrically to produce uniform illumination over defined areas, in place of individual lights serving specific purposes.

Prior to this stage of development there was little or no real justification for detailed calculation of illumination since, apart from the deficiency of the data available, there was no clear indication of the illumination required. This deficiency was remedied in 1936 by the issue of recommended values of illumination by the Illuminating Engineering Society; which were revised and published in 1941 as the I.E.S. Code, referred to previously. At about the same time there occurred a fundamental change in the method of calculating illumination. Previously, it had been necessary, in order to predetermine the illumination over an area, to evaluate the direct illumination at a sufficient number of points by the use of the inverse-square and cosine laws and to represent the result by drawing ilumination contour lines, a tedious and not always accurate process since it ignored the contribution made by surface reflections. The lumen method of design, originated by the work of Harrison and Anderson in the United States, provided a simple and, within its limits, reasonably accurate alternative which is still in general use. By this method the proportion of the total light output of the lamps which reaches the reference plane, i.e., the utilisation factor, is derived from a set of tables, largely empirical, which make allowance for room dimensions, surface reflection factors and reflector characteristics. The rest is simple arithmetic based on lamp-output data. The combination of recommended illumination values and the lumen method of design gave a scientific character to lighting design which was supplemented by the introduction of direct reading, portable light-meters with the result that it became a relatively simple matter to draw up a specification, comply with it and test the result. To this extent lighting, and particularly factory lighting, fell readily within the orbit of the engineer and most works electrical engineers to-day include among their duties that of designing lighting.

It has been obvious, however, for a considerable time, that there are many defects in this kind of lighting engineering. The lumen method of design is only applicable to symmetrical lighting layouts and guarantees neither the uniformity nor suitability of the result. It simplifies the task of the experienced lighting engineer but is a trap for the inexperienced.

It is indicative of the speed of lighting evolution that, at the time the lumen method of design was coming into general use, new light sources were being introduced which were destined to render the method obsolescent and even now when new and better design methods are slowly finding acceptance there are beginning to emerge new types of light source which may in their turn render these methods obsolescent. The emergence of new lighting design methods is a result, not only of the inadequacies of the former method, but of the tardy recognition that lighting can no longer be judged solely by objective criteria but only by its effect on individuals, who respond not only to the illumination level but to the depth and hardness of shadows, the presence of glare, the colour of the light, the pattern formed by the different brightness of fittings, ceilings, walls, etc., the way in which solid bodies are revealed or enhanced by the gradation of light and shade (i.e., the modelling): in fact, the complete interplay of light with the physical characteristics of the area to be lighted, which produces the visual field. There is a long way to go before the design of the whole visual field supersedes illumination design as now practised but much has been learned which can be applied now by engineers and is of interest to all who are connected with lighting, industrial or otherwise. It is appropriate, therefore, at this stage, to examine briefly this new approach to lighting design.

BRIGHTNESS CONTROL

The introduction of discharge and fluorescent lamps has made possible illumination levels which formerly were associated only with daylight. It is now painfully apparent that these medium to high illumination levels can bring with them serious discomfort which is not, as in the past, due to lamp brightness, i.e., is not "glare" in the commonly understood sense. Independent research on this problem in many countries has resulted in a wide measure of agreement on the factors causing this discomfort and on their inter-relationship. The aim of the research was to obtain an expression which would yield a reliable discomfort index, or number, for any normal combination of light sources (of brightness B_s) and backgrounds (of brightness B_b) The ultimate result has a simplicity which belies the difficulty of observing and testing the subjective reactions of many people over long periods. In essence, what has been learnt is that visual discomfort is dependent on the relationship between the light source brightness, the brightness of the background to the source and the illumination level E to which the eye is adapted. The relationship is expressed as follows:

$$\frac{B_s \times E}{B_b} = \text{index of discomfort.}$$

Discomfort indices so obtained are not numerically comparable one with another but represent figures of merit which fall on one side or the other of certain thresholds usually classified, in descending order of magnitude, as follows:

(*a*) Just intolerable: the border line between intolerable and uncomfortable glare.

(*b*) Just uncomfortable: the border line between uncomfortable and merely distracting glare.

(*c*) Just acceptable: the border line between distracting and acceptable glare.

(*d*) Just imperceptible: the point at which glare from the sources just ceases to be noticeable; the sources themselves are still noticeable but they merge into the general field of view in such a way that they cease to attract.

The discomfort indices of any number of individual sources are additive and it is thus possible to evaluate, in advance, the degree of discomfort likely to result from any lighting installation seen from any viewpoint. Equally important, however, is the insight which this simple expression gives into the causes and prevention of visual discomfort. For instance, it is obvious that as the illumination E increases so $\frac{B_s}{B_b}$ must be decreased to maintain the same discomfort index—or degree of comfort. This means that heavy contrasts, such as unlighted ceilings create, may be tolerable under low levels of illumination but are quite intolerable at high illumination levels, and at any illumination level discomfort is reduced by reducing the brightness contrast between light sources and their background. It also means that the illumination and colouring of ceilings, walls and surroundings generally has to be planned in conjunction with the work illumination and cannot be ignored, as was formerly the case. It is now known, furthermore, that not only comfort, but visual efficiency, is affected by the relationship between the brightnesses of different parts of the interior and that the production advantage of higher illumination can be lost by inattention to this qualitative aspect.

NEW METHODS OF LIGHTING DESIGN

It is obvious that to fulfil these qualitative requirements more precise design methods and data are required. The design problem arises out of the interplay of light among room surfaces. The illumination received at any point from a light source is a combination of that due to light received directly from the source and that due to multiple reflections between all room surfaces. Without some form of simplification the calculation of the latter, indirect, contribution would strain even the resources of an electronic computer but the problem has been found capable of ingenious simplification and tabular data are now available by the use of which the effectiveness of a prepared lighting scheme can be predetermined in terms not only of work illumination but also of the general brightness pattern of the interior, and of the comfort rating of the installation.

DESIGNED APPEARANCE

The latest stage in the process of refining lighting design involves the detailed specification of interior brightnesses required to produce a certain visual effect, i.e. lighted appearance, and the subsequent design of a lighting installation *ab initio* to produce it without the need for trial and error. Not unnaturally this is known as the "designed appearance" method and its main application at present is to the lighting of churches, and buildings where the emphasis is on effect and atmosphere. It could equally well be applied, however, to factory reception rooms, lobbies and canteens and ultimately it should be applied to all interior lighting because it is designed to satisfy, stimulate and please people in a positive sense. This is the true role of lighting and it is achieved only by happy accident, if at all, by present conventional design methods.

The foregoing may seem to be more relevant to the artist and architect than to the engineer, but it is possible to rate the engineer's role too narrowly. The paucity of industrial lighting, indeed the deficiency in the whole humanistic side of industry in the past, stems to a large extent from such a narrow interpretation of the functions and interests of engineers. The new developments in lighting design call for engineering of a high order, but engineering with a background of art and imagination, calling for co-operation with architects and artists such as is more and more in evidence in industrial design generally. The future approach to lighting diverges from the past because it relates lighting more to the needs of people, it seeks to satisfy those who produce and by so doing to contribute to the efficient factory. Unless engineers regard it as their concern this new approach to lighting will be still-born.

LIGHTING IN INDUSTRY

The previous section has been mainly concerned with the "prescription" of lighting generally. Dispensing the prescription in the factory, however, is a job for the engineer and considerable skill and experience are required to make the best use of the great variety of equipment available, for while his scope is enlarged by this variety his design task for the same reason, is complicated. The first problem facing the engineer is, therefore, to choose equipment which, in the circumstances in which it is used, will produce the required result at the lowest cost, and the following notes indicate the factors involved in this.

LAMPS AND THE COST OF LIGHTING

The characteristics which determine the suitability of a lamp from the engineering viewpoint are: (*a*) replacement cost; (*b*) associated capital costs; (*c*) luminous efficiency; (*d*) dimensions and (*e*) colour characteristics.

For most lighting purposes the engineer has to choose from the following lamp types:

Tungsten Filament Lamps.—Relatively cheap, low associated capital costs, relatively low luminous efficiency; small dimensions are convenient but introduce risk of shadow and glare.

Mercury Discharge Lamps.—Relatively costly, with a life of 4,000 hours, additional capital cost involved for control gear, high luminous efficiency, relatively small dimensions, poor colour rendering. In addition to the normal range, lamps of 1 kW and 2½ kW are available for extra high mounting.

Colour Corrected Mercury Discharge Lamps.—As above, but lamps more expensive and luminous efficiency about 10 per cent. higher in 400 watt and 250 watt range; good colour rendering. Also available in 1 kW size.

Fluorescent Tubular Lamps.—Lamp replacement costs similar to tungsten filament lamps for same service; control equipment relatively expensive; high luminous efficiency; large linear dimensions reduce shadow and glare; excellent colour rendering.

Sodium Discharge Lamps.—High replacement cost; control equipment relatively expensive; very high luminous efficiency; dimensions intermediate between fluorescent and mercury discharge; monochromatic colour rendering.

In many cases tungsten-filament, mercury (with or without colour correction), fluorescent or a blend of mercury and tungsten filament lamps are equally worthy of consideration and the selection is mainly influenced by the economics of their use. Sodium lighting has very limited application due to its inability to reproduce any but its own colour.

The curves in Fig. 7 indicate how the annual cost of providing a unit quantity of light (in this case a million lumen-hours) varies according to the conditions of use and the type of lamp used. Although the curves do not take into account the annual cost to be apportioned to reflectors, installation and maintenance they indicate very clearly the following points:

(1) Tungsten-filament lighting is relatively

Fig. 8 Absence of upward directed light produces a "tunnel" effect and accentuates glare from visible lamps.

Fig. 9 The use of translucent reflectors in large numbers can be distracting as this example from a cotton mill shows.

Continuing **Design**

expensive under all normal factory conditions.

(2) A maximum-demand tariff penalises lighting installations which are little used and favours extensive lighting usage, such as in the case of shift working. It is interesting to note that the balance of advantage changes from the flat rate to the M.D. tariff at about 2,000 hours, irrespective of the type of lamp used.

The wider implication of these curves, however, relates to a question already discussed, namely the economics of natural lighting versus artificial lighting. Fluorescent lighting used for 1,000 hours a year will cost 75 pence per mega-lumen-hour on the M.D. tariff instanced. If the fluorescent lighting is used for 4,000 hours a year the cost per mega-lumen-hour will fall to half this figure and the economic justification for the cost, direct and indirect, of glazing is correspondingly reduced. The cost of installation, reflectors and maintenance is the same for 1,000 or 4,000 annual operating hours and as these costs tend to increase so does the inducement to make more use of electric lighting. The main concern of the engineer is, of course, to design a sound lighting installation, but he will be failing in his duty if he does not see to it that this broader economic picture is made clear to the management and if he does nothing to relate his side of the picture to that of the architect so that between them they can arrive at a sensible balance between the expenditure on daylighting and natural lighting.

Fig. 10 (*left*) *Localised fluorescent lighting for automobile-finishing conveyor combined with overhead general lighting.*

Fig. 11 (*right*) *Unshielded fluorescent lamps mounted on a shell concrete roof. The high reflectivity of the concrete reduces background contrast and renders reflectors unnecessary.*

LIGHTING FITTINGS

There are literally hundreds of types of lighting fittings now available and the choice of the most suitable fitting for any job is no easy matter. Fundamentally, however, the choice narrows down to certain essential considerations which are discussed in the following paragraphs, the first of which deals with light distribution.

The form of light distribution which is now almost universal in industrial installations is that known as dispersive. This form of distribution is characterised by the production of substantially uniform illumination of an area over which such fittings are spaced apart not more than one and a half times their height. This spacing/mounting-height ratio of $1\frac{1}{2} : 1$ is the maximum normally permissible and sets a lower limit to the number of lighting points required for the general lighting of a defined area. It applies equally to tungsten-filament, mercury or fluorescent tubular lighting.

This category of fitting is further subdivided into closed-top fittings, giving no upward light, and fittings with top openings allowing a proportion of light to escape upwards. It is a common error to suppose that the latter are less efficient than the former in terms of downwardly directed light but this is not necessarily the case. A substantial portion of light reaching a closed-top reflector is absorbed by the lamp after reflection whereas if allowed to escape upwards an additional downward component is produced from the ceiling acting as a secondary reflector. It seems incredible, therefore, that unlighted ceilings and resulting glare and gloom should be tolerated, and indeed encouraged, by the preponderance of closed-top fittings offered for sale. Fig. 8 illustrates the results from such fittings. The self-cleaning effect of top opening is discussed later in relation to maintenance and is a further reason for a radical change in their present usage.

Mechanical Considerations.—One of the most severe engineering problems presented by lighting fittings is that of durability, particularly of reflecting surfaces. Fittings for tungsten or mercury lamps are small enough to be vitreous enamelled at reasonable cost, or may be of anodised aluminium, either of which finishes gives adequate durability. Fluorescent fittings, however, are less adaptable to vitreous enamelling and, although such fittings are available they are expensive and heavy. Plastic reflectors are a good substitute and have great durability. The translucent nature of the plastic used assists in producing a light ceiling but large numbers of such fittings in a single interior can be distracting (Fig. 9). There has been considerable development of flame-proof, dust-proof and corrosion-proof fittings and many varieties of fittings for special purposes, such as pit lighting, are available.

Lighting Layouts and Systems.—Most industrial lighting is "general," i.e., it provides substantially uniform lighting over a defined area. This may be a complete interior and usually applies in workshops where all the work involved is reasonably similar in its illumination requirements, where the plant or production arrangements may be subject to variation, and where obstruction does not make this arrangement impracticable. On the other hand it may be desirable to group lighting fittings in such a way as to light specific working areas to varying standards, i.e., to localise the general lighting. This form of lighting is most often used in interiors where fine or exacting work takes place over only part of the area, or where the plant or bench layout is unlikely to change, or where tall plant or shafting makes a symmetrical layout impossible; such an example is shown in Fig. 10. Local lighting may be added as required with either system but it is used to supplement general lighting, not to replace it.

Details of layout and method of installation are largely affected by structural considerations. Fittings tend to be mounted directly on to ceilings of multi-storey buildings and on roof trusses in the case of medium-height single-storey buildings. The height available for mounting lighting fittings sets a maximum to the spacing permissible and hence to the lamp wattage which can be used, the latter also being restricted by the need to avoid glare. These conditions are particularly favourable to fluorescent lighting and it is now almost an automatic choice for new installations. The increasing use of concrete-shell structures has led to much more integration of lighting with the structure. One reason for this is the need to cast fixings for the lighting equipment into the concrete to avoid expensive and untidy improvisation later. Curved-shell roofs make excellent reflectors and unshielded fluorescent lamps are often used with high utilisation efficiency and with little danger of glare since the high brightness of the lighted ceiling forming the background to the lamps reduces contrast (Fig. 11).

Provided that care has been taken to provide ample illumination, with provision for future contingencies, and to select fittings and accessories which are durable for the particular duty envisaged and give adequate glare protection, the installation of fluorescent lighting in interiors of medium height does not present any great difficulty.

High-Bay Lighting.—The lighting of very high shops is a more difficult matter and it is tempting to accept unsatisfactory solutions on grounds of cost, regardless of the fact that visual requirements are certainly no less severe than in lower shops, and that production errors may be much more serious. It is common practice to use very high wattage sources at the maximum possible spacing to keep down installation and maintenance costs and for maximum utilisation efficiency. Lamps are often housed in concentrating reflectors to confine the light as far as possible to the working area and avoid losses by wall absorption (Fig. 12). It has to be realised, however, that the lighting so produced is unsatisfactory in many ways. The shop is gloomy, shadows are hard, and not nearly enough light falls on vertical surfaces, on which much of the work is carried on. Attempts to remedy the latter defects by using portable or transportable lighting are time wasting and inconvenient and such lighting is liable to misuse, as well as being dangerous. The new approach to high-bay lighting does not accept the proposition that lighting conditions must necessarily be inferior to those in interiors of more convenient height. Dispersive reflectors are increasingly used and the loss by wall absorption is set against the light returned by reflection from the surfaces and against the greater cheerfulness of brighter surroundings (Fig. 13). In several factories additional upward-facing reflectors are used for the sole purpose of lighting the roof area. In the

most advanced high-bay lighting installations the high-level lighting is supplemented by lighting below the gantry crane, directed from the sides to the centre. Fluorescent lighting is particularly suitable for this purpose due to its low surface brightness (Fig. 14).

There is an increasing tendency to adopt fluorescent lighting even for the top lighting in high-bay workshops, the 8 ft. 125 watt lamp being commonly used (Fig. 15). Cold-cathode fluorescent lamps are sometimes used on the grounds that their very long life (about 15,000 hours) reduces the need for maintenance. This argument, however, suggests that the only maintenance required is to replace lamps, but in practice the lamps and fittings will need to be cleaned several times during the lamp life and the lamp output will, in any event, fall over this long life by a considerable proportion. The problem of maintainence is, in fact, the most intractable feature of lighting and the one concerning which little progress has been made.

LIGHTING MAINTENANCE

Lighting differs from normal engineering practice in respect to maintenance just as it does in most other respects. The normal spur to maintenance is the certainty of the failure or breakdown of equipment without it. There is no such stimulus to lighting maintenance since the result of neglect is merely a progressive run-down of illumination which is apt to escape notice until conditions become acute. The penalty for poor lighting maintenance is simply the loss of the use of light (for which the management continues to pay the full cost) and the loss, in imperceptible stages, of the benefits which it was intended to provide. Although the purpose of maintenance may differ, however, the financial equation is fundamentally the same except that, whereas in normal preventive maintenance a balance is struck between the cost of maintaining equipment and the cost of its failure, in lighting maintenance a balance should be struck between the cost of providing a margin for depreciation and the cost of preventing it altogether. In theory,the maintenance equation for a lighting installation is very simple.

Let C_m = cost of cleaning one fitting and lamp or lamps once,

D = proportion of depreciation in light output of a typical fitting per month,

And C_0 = annual cost of operating the fitting, excluding cleaning cost.

These factors can be combined to produce a "maintenance characteristic," K_m, given by:

$$K_m = \frac{12\,C_m\,D}{C_0}.$$

Then the allowance to be added to the basic calculated lamp wattage for depreciation, i.e., the depreciation factor is given by:

$$d = \sqrt{\frac{K_m}{1 + K_m}}$$

where d is the depreciation factor.

The inability of the engineer to do more than make a guess at the values of C_m and D at the design stage removes any prospect of precision in the calculation of the optimum depreciation factor, but nevertheless, the evaluation in advance of the maintenance characteristic, however inexact, will prevent the adoption, as is so often the case at present, of completely unrealistic maintenance factors and provide a useful basis for cleaning schedules in new or existing installations.

The main factor in the above over which the lighting engineer has control is the depreciation characteristics, D, of the lighting fittings selected. It can be shown that, for all but very clean situations, it is sound economics to pay considerably more for a fitting which excludes dirt, i.e., has a sealed cover glass, or for one which has self-cleaning properties. The provision of top openings greatly assists this latter process since the through convection currents created by the openings reduce dust settlement and have a scavenging effect when the lamp is alight. There is thus a further inducement to avoid

Fig. 12 Concentrated reflectors in use in a foundry. Although the light is "efficient" the absence of light on ceilings and surroundings produces cheerless and uncomfortable working conditions.

Fig. 13 Blended mercury discharge and tungsten filament lamps in dispersive reflectors produce good working conditions. Note: for maintenance purposes all fittings are directly accessible from cat-walks.

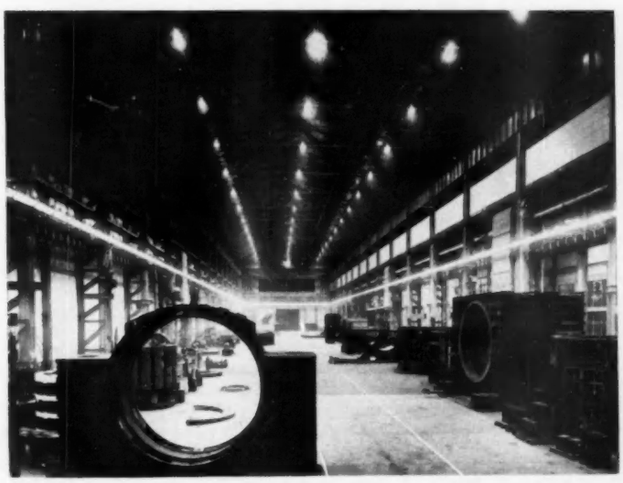


Fig. 14 A large engineering shop lighted by 1 kW mercury discharge lamps at high level, with continuous lines of fluorescent lamps in angled reflectors below crane level. Workshop conditions are excellent and the cross lighting minimises shadows and facilitates work inside castings, etc.

Fig. 15 Transformer erection bay lighted by high-mounted fluorescent lamps.

Continuing Design

closed-top reflectors except in the case of those which are sealed against the ingress of dirt.

LAMP REPLACEMENT

Lamp replacement is a more complex matter than is commonly supposed. With tungsten-filament lamps, which maintain a reasonably uniform light output throughout their life of approximately 1,000 hours, it was reasonable to replace lamps as they failed although this procedure could be expensive in labour and troublesome, since lamp failure could occur at awkward conjunctions of time and place. Discharge lamps, and more particularly tubular fluorescent lamps, with four or five times the life, present a different problem since their light output declines very considerably throughout their life and they seldom fail outright but continue to absorb their rated wattage long after they have ceased to give a useful light output. The object of an expensive lighting installation can easily be defeated by inattention to this matter and one remedy is to replace all the lamps in an interior in one operation after they have been in operation for about 80 to 90 per cent. of their rated life. The value of the lighting service thus lost is usually more than offset by the reduced labour cost of replacing the lamps due to the ability to carry out the group replacement on a convenient occasion and to fit it in with the routine cleaning, and by the maintenance of a reasonable minimum standard of lighting.

An alternative method, which overcomes the difficulty of assessing the correct group replacement interval, is "selective replacement." In this method factory areas are grouped into areas of greater, A, and lesser, B, productive importance. Failed or worn out lamps in A areas are replaced by new lamps, failures in B areas are always replaced by used lamps taken from A areas for which are substituted new lamps. Once this procedure has become established lamp failures in A areas rarely occur and continuous rejuvenation by new lamps provides continuity of illumination over these areas to a standard near to that of the installation when first put into service.

MAINTENANCE ROUTINE

Routine lighting maintenance is not a common procedure in factories, the more usual procedure being to allot this work to whatever unskilled labour may be available at the time when it is decided that the matter can be delayed no longer. The main objection to this procedure is not so much that it results in dirty fittings, for open fittings collect a dirt layer very quickly, but that it leaves the fittings too long in this condition, with the result that reflecting surfaces are permanently damaged and the installation performance is permanently degraded. This state of permanent degradation, yellow reflectors and peeling paint work, is so much in evidence as to support the view that the factories concerned would get better value from their lighting equipment by abolishing top reflectors entirely and substituting simple glare shields around the lamps. Since this solution, whatever its merits, is unlikely to appeal to most managements it is strongly recommended that maintenance be applied systematically, i.e., that cleaning be arranged at quite definite intervals whether long or short, and that lamp replacement be organised to fit into this routine.

LIGHTING OPERATION

The final link in the lighting chain is its operation. This is probably the weakest link of all, for whether the lighting available be good or bad, or however it may be maintained, it cannot serve its proper purpose unless it is intelligently used. The position in this respect is complicated by a characteristic of lighting which affects also its design and maintenance, namely, that the result of error is not immediately obvious as it is in most other branches of engineering. If the control of factory heating were to follow the same principles as that of most factory lighting the resulting complaints of over or under-heating and the dreadful waste involved would very quickly produce remedial action. Yet in lighting installations which range from the small to the very large there can be observed arrays of lighting fittings each with a pull-cord switch by which the employees exercise their individual notions concerning the minimum illumination with which they can work effectively, or which they think will not arouse comment from overseers, or which they operate only after conditions have become impossible otherwise. The outcome of the interplay of these various motives and of the differences in individual visual demands is a scene of visual chaos the only attraction of which is that it presages the end of the day's work. Indeed, there is good reason to believe that the initiation of this turgid lighting-up process marks an interruption of the working tempo which is often not restored until the following morning.

In many factories groups of fittings, chosen for convenience in wiring rather than from any relation to the penetration of natural light, are switched from odd corners of the workshop, the responsibility for this being largely undefined. In some shops it is necessary to switch on an unnecessarily large group of fittings in order to counteract daylight deficiency in a small section. The author has visited very large factories in which large areas more than adequately lighted naturally have the electric lighting switched on most of the time while other areas less well supplied with daylight were without this benefit. It is extremely difficult to understand the mixture of motives which prompt the expenditure of considerable sums of money on good lighting installations and the subsequent indifference to its non-use or mis-use.

The most convenient solution to the problem of controlling lighting is to use the lighting equivalent of the thermostat, i.e., the light-sensitive switch. (It is greatly to be deplored that the term which is most appropriate, and most descriptive of, this device, namely the "photostat," has been annexed for use in a totally different connection.) Light-sensitive switches take the form of photo-electric cells which are placed so as to receive daylight only, at some point (usually facing the north sky) where conditions typify the general state of indoor natural lighting. Small signals from these are electronically amplified and arranged to switch on electric lighting in stages corresponding to the needs of different parts of the interior. These devices have now reached a high stage of reliability and their increasing use is a good augury for the future of industrial lighting.

This is the second of three articles by Mr. Robinson. The first was published last week and dealt with the managerial problem. The third article will deal with some broader problems of design.

ECONOMIC CRITERIA AND THE CHOICE OF EQUIPMENT

Of the many forces he encounters, the engineer cannot but be impressed by the economic ones. Although he may not be aware of their exact nature, he must admit their omnipresence. The word "inflation" rarely fails to enter his daily newspaper. It is a little disturbing. Must the B.Sc.(Eng.) spend further years studying to become a B.Sc.(Econ.) before he can escape the epithet "unworldy ?"

The answer might be found in a recent paper by Mr. R. Krzyczkowski, B.Sc.(Eng.), B.Sc.(Econ.). His aim in "Interest and inflation in the economic planning of telecommunications systems" is to help engineers understand the nature of the economic forces mentioned in his title. He illustrates his arguments with a practical example: a telephone authority is thinking of replacing an open-wire trunk route by a cable or radio connection; the choice between the two is largely governed by the rate of inflation.

In the paper, published in *A.T.E. Journal* for October, the author discusses inflation and rate of interest from the point of view of their historical and economic justification and shows their interdependence. He goes on to consider the advantage of examining the competing communication systems on the basis of the "present value of annual charges," deriving the formula he uses and working out a numerical example. The current inflationary trend for telecommunication systems is calculated, extrapolated into the future, and incorporated into the "present value" calculations. In a final section the author gives an indication of the impact of the level of interest rates in the case of his chosen example.

Because Mr. Krzyczkowski takes pains to explain the terms he uses, the paper makes interesting reading—more interesting than the above synopsis would suggest. But the lay engineer will realise that he is in no position to criticise the arguments unless he has some foundation knowledge in economics. Perhaps a course in the subject would be a good idea after all.

BUILD YOUR OWN COMPUTER

An analogue computer is so called because it constructs an analogue of the equation it has to solve. In an electrical computer of this type, the complex electrical representation of a particular problem will be built up of a large number of smaller electronic analogue units. Each electronic unit will perform a particular function such as integration or addition, or multiplication.

Since any particular mathematical problem will require a certain series of mathematical operations, the computer to solve the problem will need to be built up of a particular collection of electronic units. When it is necessary to use the computer to solve a different mathematical problem a different collection of units will be required. Thus a general-purpose analogue computer tends to be a rather wasteful machine, for, if it is used for a variety of problems, many of its units will not be in use all the time. Generally it is better to construct an analogue computer for a specific type of problem.

To enable firms to build their own analogue computers, Solartron Electronic Group Limited, Thames Ditton, Surrey, are producing a range of the basic electronic units. The fundamental unit is the drift-corrected computer amplifier. It can be used for summing, sign reversing, and integrating. A frame can be supplied that will house five amplifiers and a heater supply unit. The frame fits into a standard 19 in. rack. Printed wiring is used extensively in the equipment. The amplifier long-term drift, referred to the input, is less than 100 microvolts, and the effective grid current is about 10^{-10} amp.

Other units available are power supply units providing 300 volts (the a.c. resistance between 20 c/s and 200 kc/s is less than 0·5 ohms) and ventilating panels. Under development are a computer amplifier with a higher power output; a linear computing unit containing potentiometers, precision resistors, relays and capacitors; and a crossed fields multiplier that is expected to have an accuracy of $\pm 0{\cdot}25$ per cent. at frequencies up to 1 kc/s.

Production

CONTINUOUS THICKNESS MEASURING OF THIN, SOFT SHEET*

Pneumatic Gauging Technique

By J. C. Evans, B.SC., PH.D., *I. G. Morgan*, M.A., *B. S. W. Mann*, A.M.I.MECH.E., *and F. C. P. Mason*, G.I.MECH.E.

A new machine for the continuous measurement during production of thin, soft material, e.g. cellulose acetate film, has been developed at the National Physical Laboratory and has successfully undergone factory trials. The measurement is made without compressing the material and an accuracy of ± 20 microinches (± 0·5μ) is obtained for thicknesses in the range 0·001 to 0·02 in. (0·025 to 0·5 mm.).

A requirement in many industries is the measurement during production of the thickness of material made in sheet form. A particular requirement arises in the manufacture of very thin sheets of soft material, for example, cellulose acetate, polyethylene, and rubber, where thicknesses in the range 0·001 to 0·02 in. are usual and where, for technical or economic reasons, it is necessary to determine the thickness with an accuracy of a few per cent. It seemed that in such cases a method of measurement based on pneumatic gauging might be of value, particularly on account of the high accuracy needed, but also because such soft materials are easily compressed by devices which measure by contact.

The apparatus[1] described in this paper was accordingly developed. It will measure the true thickness of the sheet, i.e., its thickness in the uncompressed state, to an accuracy of ± 0·000,02 in. Measurement may be made at as many positions as desired across the sheet which, in principle, may be of any width. The thicknesses at those positions can be indicated continuously and simultaneously, a feature of considerable advantage during the preliminary adjustment of the plant to give the required thickness; in addition, the thickness at any one position can be continuously recorded on a chart, this position being selected at will by means of a pneumatic switch. The nominal thickness of the sheet can have any value, subject to the requirement that the sheet must lap satisfactorily on a roller introduced into the production line to serve as a datum for the measurement, i.e., the material must be sufficiently flexible to allow the lower surface of the sheet to maintain intimate contact with the roller across the full width.

When measuring thickness by pneumatic gauging two methods are available. In the first, the work to be measured is placed between two opposing jets to which air is supplied simultaneously through a suitable constriction by a source kept at a constant pressure greater than atmospheric. Change in thickness of the work alters the escapement of air from the jets and this results in a change in the pressure between the jets and the constriction. In a correctly designed pneumatic circuit, this pressure change is proportional to the thickness change so that variations in thickness can be determined by measuring the corresponding variations in pressure. The method has certain disadvantages for the present application, bearing in mind the accuracy postulated: it requires that the sheet shall be held very closely central between the jets; also, for calibration purposes, it calls for an accurate standard of the same nominal thickness as the sheet, a demand which it is extremely difficult if not impossible to meet.

In the second method, the work is placed on a datum surface and a single jet blows directly on the work. This jet is likewise supplied with air through a suitable constriction by a constant pressure source and the pressure between the jet and the constriction measured. It can be arranged that this measured pressure is proportional to the distance of the jet from the free surface of the work.[2] If, then, the distance of the jet from the datum surface is kept constant and the work is correctly registered on the datum surface, variations in this distance will be due solely to changes in thickness of the work, which will thus be determined by the corresponding pressure changes. For the application in mind, a convenient datum is made available by inserting a suitable roller into the production line, with auxiliary guide rollers to ensure that the sheet, whilst passing over the datum roller, laps it satisfactorily. A linear array of jets spaced uniformly across the sheet so as to blow normally on to it during its passage over the datum roller will then provide information about the thickness at as many stations across the width as is required.

* Communication from the National Physical Laboratory.

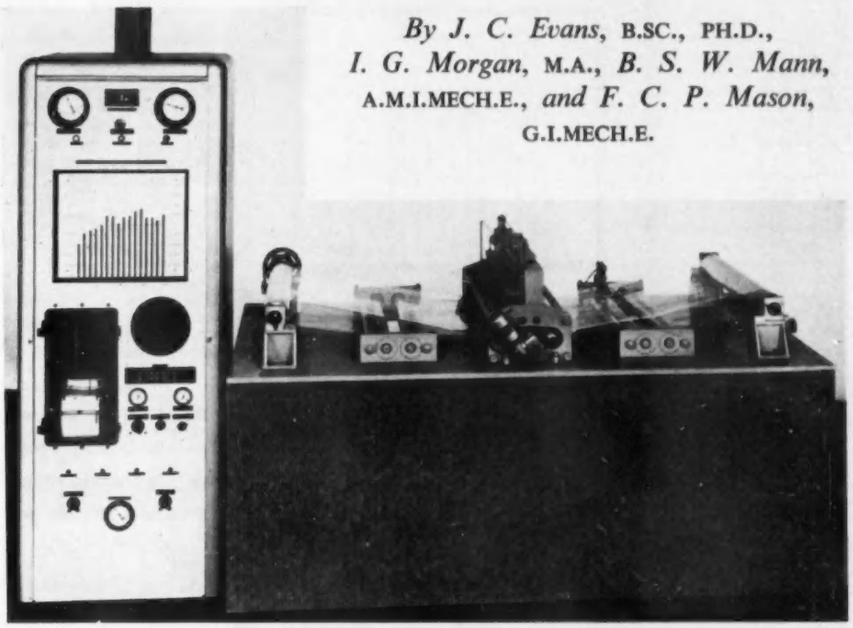


Fig. 1 The pneumatic gauging machine has been developed for the continuous measurement during production of thin, soft material such as cellulose acetate film. An accuracy of ± 20 microinches is obtained for thicknesses ranging from 0·001 to 0·02 in.

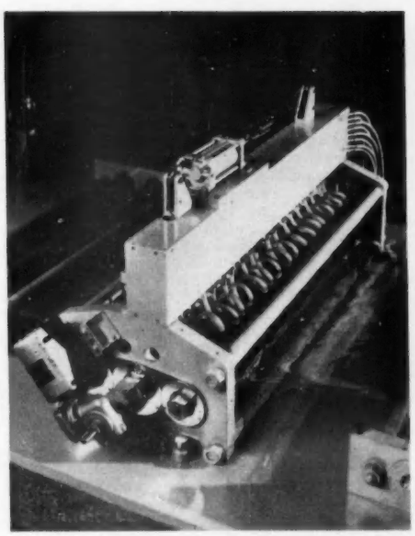


Fig. 2 The measuring head. The film passes over a datum roller and underneath a line of air-jets blowing normally on to the free surface of the film. The air-jets are carried in a Y-beam which itself rides on the datum roller, so that eccentric displacements are imparted equally to jets and to sheet.

Since it is important in the manufacture of soft sheet material that the surfaces of the sheet are not scratched, it is necessary to ensure that there is no relative motion between the sheet and the surfaces of the rollers. The rollers must therefore revolve freely so that they may be driven by the sheet. When an accuracy better than ± 0·0001 in. is wanted, this requirement leads to difficulty because of the error introduced by eccentricity in the rotation of the datum roller in its bearings. The difficulty can be overcome, however, by arranging that the air-jets are carried in a beam which itself rides on the datum roller, so that any eccentric displacements are imparted simultaneously and equally to the jets and the sheet. As will appear later, the roller need not necessarily have an accurate cylindrical form, provided it is a solid of revolution.

Fig. 1 shows the measuring head and the associated measuring and recording units of an apparatus made for measuring cellulose acetate film of width 24 in.* Fig. 2 shows one side of the measuring head in more detail and Fig. 3 shows the display units on a larger scale. The rollers are housed in a rigid framework which can be placed at a suitable point in the production line. The central datum roller has a diameter of 2½ in. and the two guide rollers are each of 2 in. diameter. They are mounted in self-aligning bearings, and the film passes under the forward guide roller, over the datum roller and then under the rear guide roller. (The film drives all three rollers; the motor to be seen in Fig. 2 is used for another purpose which will be referred to later.) 16 jets, spaced uniformly in line across the sheet, are mounted in a beam of inverted Y-section (Fig. 4), the beam itself being supported on the roller by means of four locating pads, two at each end. The jets lie in a plane which passes through the axis of the roller and the centres of the two locating pads on one side of the beam. A counterpoise reduces the effective weight of the beam so as to make the bearing load at each pad about 1 lb., which is considered to be the minimum that will ensure adequate reproducibility of location.

It is clearly necessary to reduce friction at the locating pads as far as possible and at the same time avoid having to lubricate the surfaces. To this end, sintered bronze plates impregnated with Teflon are used for the actual bearing surfaces which contact the roller. In each pad assembly (Fig. 4), the bronze plate is backed by a machined and lapped steel block, to which it is fastened by an epoxy resin, such as Araldite, and between this block and a machined and lapped underface on the beam is inserted a precision spacer, the purpose of which will be described later. The block and bearing are secured to the beam with minimum distortion by a stud which, after passing through a hole in the beam and a slot in the spacer, screws tightly into a cylindrical plug located in a central hole in the block. The plug is made a good sliding fit in the hole so as to distribute evenly the force produced by the clamping nut. The reduction of friction achieved by the use of polytetrafluorethylene has, as was hoped, been of

* This photograph shows the apparatus as set up at the 1957 British Plastics Exhibition when it was shown measuring a continuous loop of film.

Continuing Production

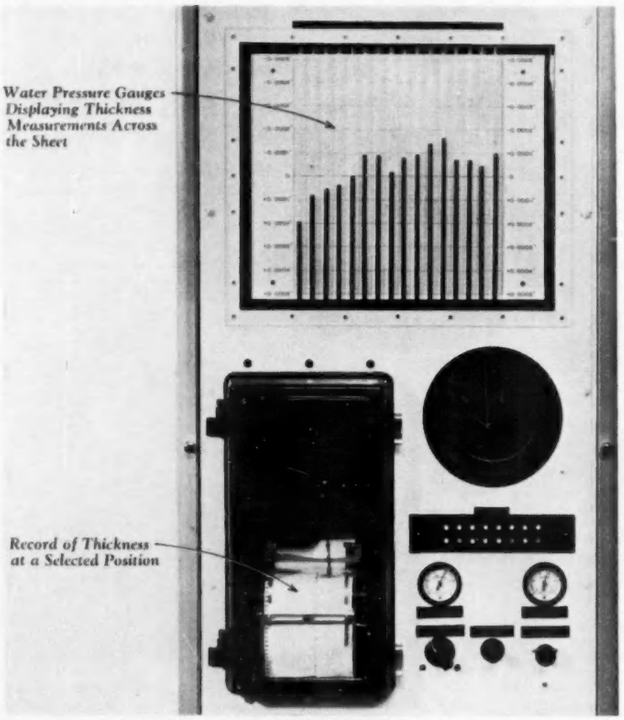

Water Pressure Gauges Displaying Thickness Measurements Across the Sheet
Record of Thickness at a Selected Position

Fig. 3 (left) The display units, rotary selector valve, and bleed valves.

Fig. 4 (right) Arrangement for locating Y-beam on the datum roller, showing a locating pad and measuring jet.

considerable benefit from the point of view of wear: after several hundred hours' running, the wear of the roller was too small to measure.

Each of the 16 jets is supplied with air through a suitable constriction from a manifold maintained by means of a pressure regulator at a constant pressure P (2 lb. per sq. in. above the ambient atmospheric pressure). The pressure p between constriction and jet is measured by means of a water pressure gauge, as shown schematically in Fig. 5. The 16 water gauges have a common air-tight cistern, the pressure in which is also kept at the value P by virtue of its connection to the manifold. The air escapement at the jet depends on the thickness of the film, and proportionality to 1 per cent. between thickness and pressure p is realised[2] provided that $\frac{p}{P}$ lies within the range 0·6 to 0·8. An increase in thickness leads to an increase in p and therefore to a depression of the water level. Further details of the pneumatic circuit will be given later.

ADJUSTING JET POSITION

For the purpose of adjusting the distance of the jets from the datum roller, the rear end of each jet (Fig. 4) is threaded to take a screw ring which enables the jet, after it has first been pushed too near to the roller, to be withdrawn gradually; when correctly located, the jet is locked in position by a tangent-bolt. The criterion used in locating each jet is that the pressure p shall be made 0·7P, which defines the centre point of the linear working range. Though this adjustment must be made with reasonable precision, it need not be exact; the adjustable bleed-valve shown in Fig. 5 enables the final position of the water meniscus to be set easily and accurately. The bleed-valve is in parallel with the measuring jet and offers an alternative escapement for the air which passes through the constriction; it is a convenient " trimmer " which does not alter the sensitivity of the circuit, provided that the leakage through it is not too large. This initial adjustment of the jets is made with the roller bare and rotating at about 15 r.p.m. so as to smooth out the small residual periodic error arising from the impracticability of making the roller a perfect solid of revolution. The motor and gear-box seen in Fig. 2 are provided solely for driving the datum roller during this initial adjustment; during the measurement of the film, as was mentioned previously, the roller is driven by the film itself.

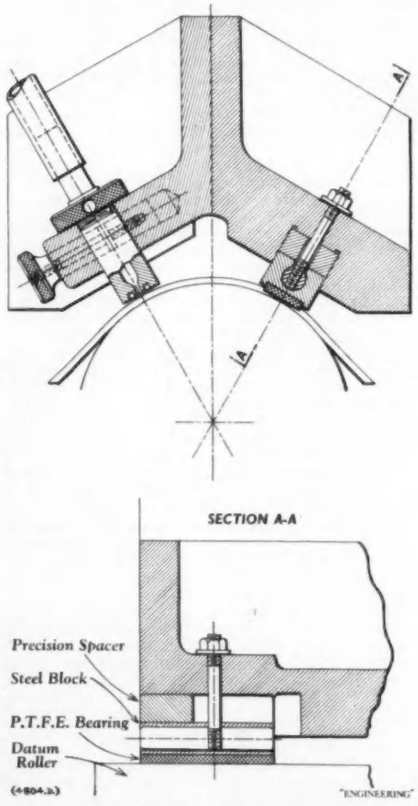
This preliminary adjustment having been made, the head is prepared for measuring any given film by increasing the distance of the jets from the roller by an amount equal to the nominal thickness of the film. Then, when the film is in place on the roller, the water-gauge readings will be unaltered if the film thickness is correct; if not, the departures from the nominal value will be shown by the changes in the water levels. The required increase in the separation between the jets and the roller is achieved by changing the precision spacers in the four locating pad assemblies (Fig. 4), and for this purpose the outer end faces of the spacers are threaded to receive a screwed rod which enables them to be withdrawn end-wise when the clamping screws have been slackened. Precision spacers of thickness 0·25 in. are used for the preliminary adjustment and other spacers are provided, in sets of four, which have thicknesses exceeding the basic 0·25 in. size by amounts corresponding to the nominal thicknesses of the different sizes of films being produced. The sizes of all the spacers, which have flat and parallel lapped faces, are known to an accuracy of ± 0·000,003 in., and their use avoids the difficulty mentioned earlier of preparing accurate standards of the same nominal thickness as the film. It will be clear that when it is required to change from one film thickness to another it is only necessary to change to the appropriate spacers; in other words, it is unnecessary to repeat the preliminary adjustment of the jets to the bare roller, though it would be advisable from time to time to check this adjustment by replacing the basic 0·25 in. spacers and verifying that the water-gauge readings are correct.

It was mentioned earlier that the datum roller need not be an accurate cylinder provided that it is a solid of revolution, though departures from the cylindrical form must not be so great as to prevent the film being properly registered on the roller. It will be appreciated that this relaxation stems from the method of adjusting the jets to the bare roller, since the procedure adopted automatically makes allowance for any departure from the cylindrical form. The surface of the roller must have a good finish, such as would be obtained, for example, by fine grinding, in order to avoid the error which would be introduced if the texture of the surface differed appreciably from that of the film.[2]

To obtain a sensitivity adequate for measuring the film to an accuracy of ± 0·000,02 in. the distance between the jets and the free surface of the film must be about 0·001 in. It would be extremely difficult to thread the film through so small a gap and it was therefore arranged that the beam carrying the jets could be lifted for this operation; a spring-loaded air-cylinder mounted on the top of the framework, as shown in Fig. 2, was introduced for this purpose. To maintain the beam in the measuring position, air is supplied to the cylinder at a pressure of about 12 lb. per sq. in. which is sufficient to neutralise the force of the internal spring; when the pressure is reduced the spring lifts the beam.

PNEUMATIC SYSTEM

Each jet has an internal diameter of 0·040 in. and is of the form depicted in Fig. 6. The constriction through which the air from the constant-pressure manifold first passes (Fig. 5) is simply a hole about 0·025 in. diameter in a brass disc of thickness 0·01 in. The bleed-valve is a miniature needle-valve. When the pressure measurements are made by means of the water gauges, the overall sensitivity of the apparatus, defined as the ratio of the change of water level to the change of thickness which produces it, is 12,500 approximately, so that a change of thickness of 0·0001 in. is represented by a change of level of the water column of about 1·25 in. It is, of course, desirable to provide the same sensitivity at each measuring station; to achieve this, the 16 jets must be made as nearly as possible identical and the 16 constrictions must be closely matched. The sensitivity is conveniently checked before the jets are mounted in the beam by means of a large-drum micrometer with a non-rotating spindle



set up in an auxiliary pneumatic circuit. Using one of the constrictions only, each jet in turn is arranged to blow directly on the flat end of the spindle and the sensitivity measured by displacing the spindle through known amounts. Then, using one of the jets, the constrictions can be similarly tested. In this way, by adjusting the constrictions when necessary with the aid of a fine tapered reamer, it is not difficult to match the sensitivities of the 16 circuits to the required precision.

For production purposes there would be no point in displaying small short-term variations in thickness, and the response of the water gauges was therefore damped by inserting a suitable constriction at the bottom of each tube. The water levels then remain practically stationary if there is no long-term change of thickness and they show at a glance the distribution of thickness across the sheet. A graduated scale placed behind the tubes enables the true thickness at any of the measuring stations to be read.

For recording the thickness at any point the pressure p is amplified by means of a spring-loaded bellows coupled mechanically to a pneumatic amplifier (Fig. 5). In this way, the variations in p are first converted by the bellows into proportional

displacements and thence by the amplifier into proportional pressure changes in the range 2 to 14 lb. per sq. in. The full pressure change of 12 lb. per sq. in. is obtained from a bellows displacement of $\frac{1}{4}$ in. and the rating of the spring-loaded bellows is adjusted so that this displacement corresponds to a change of film thickness of 0·001 in. The pressure from the transmitter is fed to a pressure recorder which has a sensitivity such that a pressure change of 1 lb. per sq. in. moves the pen of the recorder 0·3 in. When the pressures are recorded, therefore, the overall sensitivity of the apparatus, i.e., the ratio of recorder pen travel to the change of thickness which produces it is about 3,500. Provision is made for introducing such damping as is required. The principle of operation of the amplifier, which is completely free from drift, has been described in an earlier paper.[3]

A selector switch is provided to enable the amplifier to be connected at will to any one of the 16 measuring stations. It comprises a ring of 16 Schrader valves so mounted that pressure tappings may be brought from the pneumatic circuits to one end of each valve whilst the other ends of the valves communicate with a common chamber connected to the amplifier bellows. This chamber is rendered air-tight by a Neoprene diaphragm clamped across its end and over the diaphragm is mounted a disc which can be

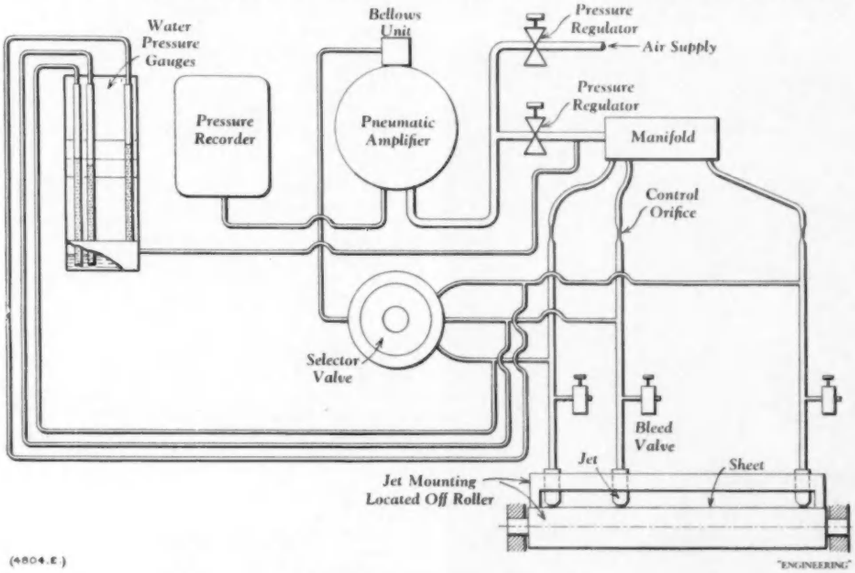


Fig. 5 The pneumatic circuit.

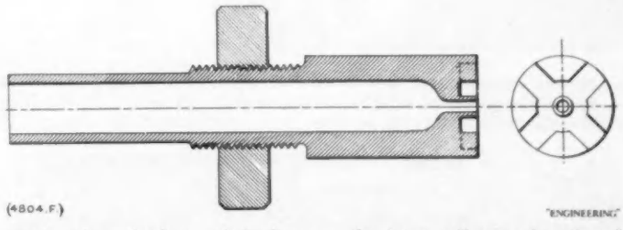


Fig. 6 Section through a measuring jet.

rotated to bring a protruberance on its under-face adjacent to any one of the Schrader valves. On depressing the disc the protruberance engages the valve stem through the interposed flexible diaphragm, so opening the valve and connecting the chosen pneumatic circuit to the bellows. A spring-loaded plunger engaging appropriately placed notches in the periphery of the disc ensures proper location of the protruberance in relation to the selected valve and provision is made for locking the disc in any chosen position.

It has been suggested to the authors that more useful information would be provided if, instead of recording the variation of thickness with time at any one of the measuring stations, the apparatus were designed to record the mean thickness across the sheet. It would be feasible to do this by taking pressure tappings from say, half the measuring stations to a stack of capsules placed end-to-end, and then measuring and recording by the pneumatic technique the changes in the overall length of the stack. In this way, the pressures at the chosen stations, connected individually to the capsules, would be added together mechanically and the overall length of the stack would at any instant represent the mean thickness across the sheet. This proposal is to be tried experimentally when the capsules become available.

PERFORMANCE TRIALS

For its first trials the apparatus was set up at the Laboratory. No difficulties were encountered in bringing it into operation and, over a period of three months during which it was demonstrated to manufacturers interested in its possible application to their production, it functioned satisfactorily. These trials were made with a continuous loop of cellulose acetate film so that it was possible to obtain records of repeated measurements of the film. Such records were always found to be in agreement to well within $\pm$ 0·000,02 in.

An error in the absolute value of the thickness could arise from any of the following causes:—(1) incorrect sizes of the spacers used in the locating pad assemblies; (2) difference between the surface finish of the datum roller and the film; (3) improper location of the beam on the datum roller. Of these, only the last needed investigation since the sizes of the spacers were known to within 0·000,003 in., and the surface finish of the datum roller was sufficiently like that of the film to render any error from this source quite negligible. The accuracy of location of the beam on the datum roller was investigated with the aid of an air-jet carried by the beam and blowing directly on the roller. The joint in the loop of film was too thick to pass beneath the jets and a pneumatic sensing device was introduced to signal the arrival of the joint at a point in advance of the measuring head; this signal was used to trigger the air-cylinder and so lift the beam automatically, the beam being lowered again when the joint had passed through. This regular raising and lowering of the beam enabled a very extensive examination to be made of the accuracy of location of the beam on the datum roller and it was found that uncertainty in the location never exceeded $\pm$ 0·000,002 in.

After these laboratory tests, the apparatus was installed, by courtesy of Courtaulds Limited, Coventry, on one of their production lines manufacturing cellulose acetate film, where it gave trouble-free service for a period of about five months. It was found to be of considerable advantage in the initial adjustment of the plant and, of course, it provided the operator with a continuous indication of the distribution of thickness across the sheet during the production run. Courtaulds, at the conclusion of this trial, made the suggestion mentioned earlier, that a record of the mean thickness across the sheet would be useful.

ACKNOWLEDGMENTS

The need for equipment to measure accurately the thickness of soft sheet materials during production was first drawn to the Laboratory's attention by Courtaulds Limited, and the authors wish to acknowledge the assistance they have received from Courtaulds, firstly in defining the conditions in which the equipment must operate and secondly in providing the facilities for the factory trial.

The authors also wish to acknowledge the help they received from Mr. A. J. Garratt, M.B.E., who suggested the use of pneumatic gauging for the measurement and of water gauges for the display, from Mr. L. W. Nickols who initiated the idea of eliminating eccentricity error by mounting the air-jets in a beam which itself rode on the datum roller, and to Mr. W. F. Atkins who made a number of suggestions in connection with the design of the measuring head. The apparatus was built in the Metrology Workshop under the direction of Mr. J. R. White.

The work described above has been carried out as part of the research programme of the National Physical Laboratory and this paper is published by permission of the Director of the Laboratory.

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[1] British Patent Application No. 12725/56.
[2] Evans, J. C., "The Pneumatic Gauging Technique in its Application to Dimensional Measurement," *J. Inst. Prod. Engrs.*, vol. 36, page 110 (1957).
[3] Evans, J. C., Graneek, M. and Loe, H. G., "Continuous Pneumatic Gauging of Materials in Thread or Wire Form," *Trans. Soc. Instrum. Tech.*, vol. 2, page 36 (1950).

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COMETS ON THE WAY

Production of the Comet 4 series of airliners by the de Havilland Aircraft Company, Limited, Hatfield, is now well under way. The first production machine, on which certification flying will be completed, is expected to fly early in the New Year. Much of the necessary flying for certification has already been completed in the Comet 3 prototype, which is representative aerodynamically and has the same type of Rolls-Royce Avon engines as the Comet 4 Intercontinental. The second aircraft will be used for pressure-fatigue tests to destruction. The third and fourth machines are at present in the equipment bay being fitted with flying controls, hydraulic and electrical services, sound-proofing and furnishings. The first deliveries to British Overseas Airways Corporation will take place in the latter part of 1958.

De Havilland have announced a third variant of the Comet 4 family—the 4C, which will have the larger-capacity fuselage of the Comet 4B Continental (destined for British European Airways) in conjunction with the long-span wing of the Intercontinental Comet 4 (B.O.A.C's machines). This version, de Havilland state, will offer the superior operating economies of the Continental Comet 4B with a payload-range capability only slightly less than that of the Intercontinental Comet 4.

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THICKNESS GAUGING

Applications of the Atomat thickness gauge, made by the Baldwin Instrument Company, Limited, Dartford, Kent, are the subject of a 15-minute 16-mm. black-and-white sound film, "Nucleonic Measurement," made for Baldwin by the Sidcup Film Unit. Atomat gauges are of two types: the transmission gauge, which measures the radiation from an isotope which penetrates the material being measured and gives an indication of the weight per unit area; and the back-scatter gauge, used when only one side of the material is accessible, which measures the reflected radiation. Copies of the film may be borrowed on application to the company.

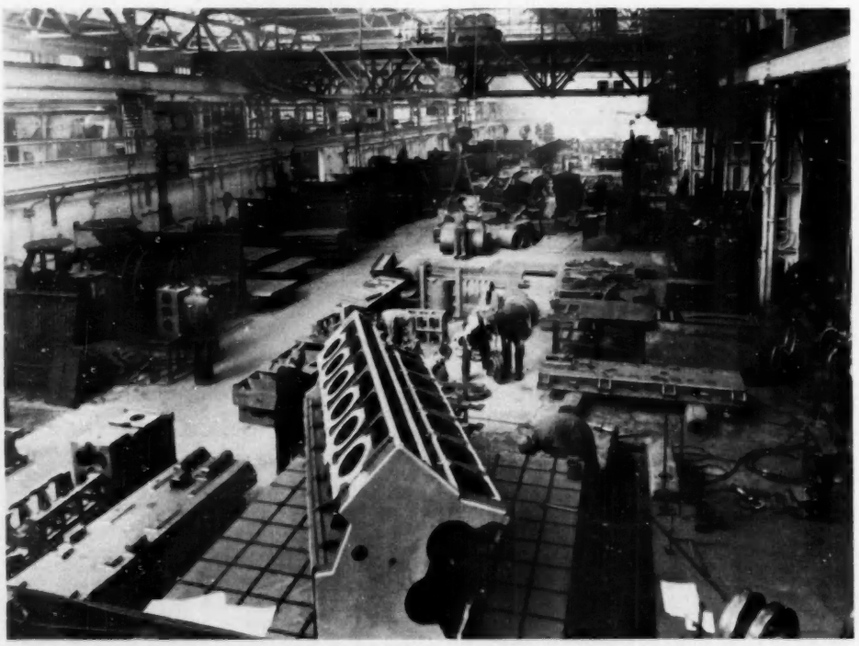
Continuing **Production**

FABRICATED STEEL TO ORDER

SINGLE ITEMS OR LONG RUNS

Production of welded steel fabrications by J. and H. McLaren, Limited, Airedale Works, Leeds, 10, was originally for internal works use only, but it has grown to such an extent that only a part of the output of the fabricating shops is now for McLaren products, and a comprehensive fabricating service is operated for the engineering industry generally. To meet present-day demands the fabricating shops have been reorganised, and new equipment installed; fabrication is now carried out in what is virtually a self-contained factory within the McLaren organisation. Structures of all sizes and types from a few pounds in weight up to 15 tons are produced. The equipment is equally suitable for bulk production work or for " one-off " or small-quantity welded components. Of the former an example is provided by the range of lighter work can be handled on an Oliver $\frac{3}{16}$ in rotary shear. A Noble and Lund 12 in. cold-saw and a group of power hacksaws deal with sections and bars. There is also a Scriven roller levelling machine capable of taking plates up to 1 in. by 6 ft., and a Town 6 ft. radial drilling machine which is used for rough work, such as drilling holes to start flame cutting. Two 5-ton overhead electric travelling cranes span the whole working area.

Material prepared in this shop passes to the first of three fabricating and finishing shops, each of which is served by 15 ton overhead electric travelling cranes. In the first shop, 200 ft. long and 31 ft. wide, plate preparation is taken through its final stages, and the prepared pieces are assembled and tack welded. Electric welding points are provided in this and the adjoining shops, the total number of points available being 20 of 300 amperes and 15 of 600 amperes. Hand-held gas-cutting torches are also used in the plating section of this shop for edge-preparation and for final shaping on assembly where necessary.

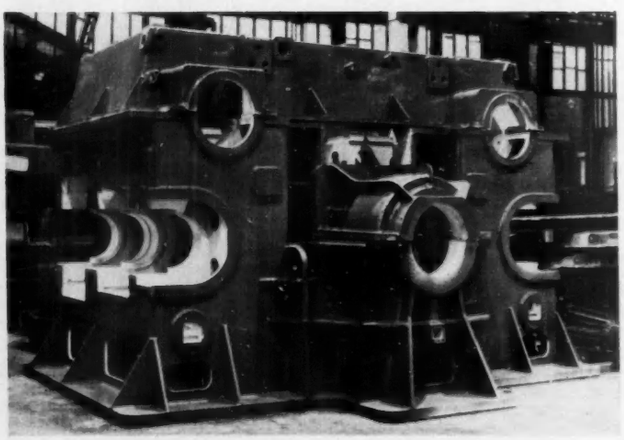


Typical McLaren fabrications include the 12-cylinder Mirrlees V-engine block seen in the foreground, and the air bottles in the middle distance. Only a part of the output of what is virtually a self-contained organisation is taken up by the internal requirements of the firm.

compressed air bottles which is in normal quantity production; of the latter, special fabrications made recently for free-piston engines, are typical, as are the multi-cylinder Diesel engine blocks which are made for an associated company. Welding is undertaken to Lloyd's Class 2 standards, and to the requirements of other classification authorities. Fabrications can be supplied fully stress-relieved and in the " as fabricated " condition or machined as well if required.

MATERIALS PREPARATION

Plates, rolled steel sections and bars are cut to size and shape in a shop, 250 ft. long and 45 ft. wide, which is solely devoted to this work. It is equipped with a group of four single-head flame-cutting machines and one triple-head machine, the latter being capable of dealing with plates up to 20 ft. long and 5 ft. wide. Material up to 12 in. thick can be cut by all these machines, which take their oxygen from the works pipe line and use bottled propane gas as fuel. For straight-line cutting up to $\frac{3}{4}$ in. thick there is a Sedgwick guillotine of 8 ft. capacity, while



A Modern Wheel Drive gearbox fabrication typifies the larger products of the McLaren fabricating shops.

WELDING

In the second of the fabricating shops, where the welding is completed, there is a floor area of 280 ft. by 52 ft. On one side of the shop facilities are provided for plate rolling and bending; the equipment includes a Bronx 5 roll machine capable of taking plates up to 8 ft. by $\frac{7}{8}$ in. cold, or 2 ft. 6 in. by 2 in. hot, and a 15 ft. by $\frac{1}{2}$ in. Sedgwick folding machine. Plates rolled or folded in these machines can pass either to the plating and tacking section or to the welding floor, as required.

Welding is entirely electric, being carried out by hand in the case of the more complicated fabrications, and by machine where long straight or circumferential seams are required. For this type of work there is a Lincoln submerged-arc welding head with a 23 ft. traversing boom and rotating gear capable of dealing with cylindrical vessels up to 8 to 10 ft. diameter.

In the third shop, which measures 250 ft. by 36 ft., there is a gas-fired stress-relieving furnace, 23 ft. long, 7 ft. 6 in. wide and 4 ft. 3 in. high over the winch-hauled charging wagon. Fabrications greater in height than 4 ft. 3 in. can be dealt with by charging them direct to the furnace hearth; in this way a maximum height of approximately 5 ft. 5 in. can be accommodated.

There are facilities in this shop for the dressing of welds and finishing of fabricated components, and for hydraulic testing of pressure vessels. Equipment for power hammer and hand forging of any component parts required in the fabrication section is installed in this part of the factory, and a gas-fired heating furnace and a hydraulic press enable hot-pressed parts such as dished ends for air bottles to be made. Complete fabrications can be shot-blasted if required, the facilities including a Tilghman 5 ft. by 5 ft. shot-blast cabinet for batch work or small single items, and a larger cabinet which will take up to the same size as the stress-relieving furnace, that is 7 ft. 6 in. wide by 4 ft. 3 in. high.

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HIGH-SPEED GROUND TOOL BITS

A range of high-speed molybdenum steel ground tool bits is now being made in the United Kingdom by the Cleveland Twist Drill (G.B.) Limited, Peterhead, Scotland, a new British subsidiary of the American Cleveland Twist Drill Company. The new bits, which are in two grades, Mo-Max and Mo-Max Cobalt, are also marketed by E. P. Barrus (Concessionaires) Limited, Brunel-road, Acton, London, W.3.

All the bits are of square section with a 10 deg. bevel on each end. They range in size from $\frac{1}{8}$ in. square by $2\frac{1}{2}$ in. long to $1\frac{1}{2}$ in. square by 10 in. long, and in a comparable range of metric sizes. Exceptional wear resistance and fast cutting speeds are claimed for Mo-Max tool bits; in particular, Mo-Max Cobalt bits, the manufacturers state, have proved in comparative tests with other bits to result in a 43 per cent. higher production of nickel-molybdenum steel workpieces at 135 to 150 ft. per minute, surface speed.

Atomic Review

Growing Pains

ALL growth calls for readjustments of one kind or another. Technical development is no exception and it would be surprising if the rapid advance of nuclear technology were not accompanied by growing pains. The accident at Windscale is an error of adolescent years, when errors are a necessary part of education and readjustment. One of the principal causes of the accident was a phenomenon known as Wigner effect. The tendency for graphite to grow as a result of this effect and the design of graphite moderators to allow for such growth, provide the second subject of the present article. In addition, Wigner growth leads virtually to locked-up stresses, and readjustment in this case is effected by annealing. At Windscale it was this readjustment which caused the trouble.

Wigner Effect

Atoms of materials in or adjacent to a reactor core may be displaced from their normal positions in the crystal lattice by fast moving neutrons. Such atoms may be transferred to vacant sites in the lattice, thereby taking up new equilibrium positions; or be forced into interstitial positions, thus leading to residual defects. These defects may conveniently be regarded as locked-up stresses, which may be released by annealing. The energy of distortion, derived from the bombarding neutron, is known as Wigner energy, and is sufficient once an initial heating has been applied to provide self-heating, whereby the annealing process may be continued. Another manifestation of Wigner effect is a preferential displacement of atoms in accordance with the crystal lattice. Thus growth may occur in one direction and none, or perhaps contraction, in another at right angles to the first. The effect was predicted by E. P. Wigner in 1942.

Windscale Inquiry

Following the accident at Windscale No. 1 Pile on October 10, 1957, the United Kingdom Atomic Energy Authority set up a committee of inquiry to investigate the accident, the methods taken to deal with it and its consequences. The committee comprised Sir William Penney, Dr. B. F. J. Schonland, Professor J. M. Kay and Professor Jack Diamond. "A less technical version" of their report is published in a White Paper (Cmnd. 302, price 1*s.* 3*d.*) which appeared on November 8, when the Prime Minister made a statement on the subject in the House. The result of the accident was a release of iodine vapour through the stack, though the filters retained most of the particulate matter. The danger from radioactive strontium and caesium was said to be negligible. The general arrangement of one Windscale reactor is shown in Fig. 1. Previous references to the incident have appeared in Atomic Review last week and on October 18.

Causes of the Accident

The immediate cause of the accident was the application too soon and at too rapid a rate of a second nuclear heating during a controlled release of Wigner energy—a periodic maintenance operation. Nuclear heating is obtained by raising the power level of the pile until its heat output is at the required value. The second nuclear heating was applied because it was thought that the Wigner release was dying away and that parts of the graphite structure would therefore escape being annealed. The instrumentation of the pile was not sufficient in quantity or in distribution throughout the pile to enable a reliable judgment to be made. The second nuclear heating led to the accident by causing the failure of one or more cartridges, the contents of which then oxidised slowly, eventually leading to the fire. By far the most likely possibility is that the second nuclear heating caused the failure of one or more uranium fuel cartridges. A second possibility, which cannot be entirely eliminated, is that it was a lithium-magnesium cartridge which failed. (Lithium is irradiated to form tritium, a heavy isotope of hydrogen used in fusion reactions.) The second nuclear heating may have released pockets of Wigner energy at a time when the general level of temperatures throughout the pile was high. During the afternoon of October 10, the operating staff of the pile thought they had a bad burst of a fuel cartridge. At 4.30 p.m. visual inspection through a plug hole in the pile wall revealed glowing fuel cartridges. Various actions were taken and by about midnight the major decision had been made that, if other measures failed, water was to be used to reduce the fire.

The Authority state that secondary causes were inadequacies of the instrumentation provided for the maintenance operation, and faults of judgment by operating staff attributable to weaknesses of organisation. As the responsibility was primarily collective, no disciplinary action is to be taken against any individual.

Evaluation Committees

The Authority have suggested that the Prime Minister appoint some independent person of standing to undertake a comprehensive evaluation of the incident and the technical and organisational remedies required. Sir Alexander Fleck, chairman of Imperial Chemical Industries, Limited, has accepted this task, as chairman of three committees: a technical evaluation committee, an organisation committee, and a health and safety committee. Windscale No. 2 Pile will not be put in operation until this work is complete.

Short Doses of Radiation

In the light of the findings of the inquiry committee, the Authority have requested the medical research council to lay down rules for the maximum permissible level of exposure to radioactive substances when exposure takes place for a limited period rather than as a continuous life-time dose.

Wigner Release at Windscale

The phenomenon of the storage of energy in graphite due to neutron bombardment (the so-called Wigner energy) has been known for some time but when the Windscale pile was designed and built knowledge was scanty. That such energy could be released spontaneously or by annealing was not clear at the time. A spontaneous release of Wigner energy occurred

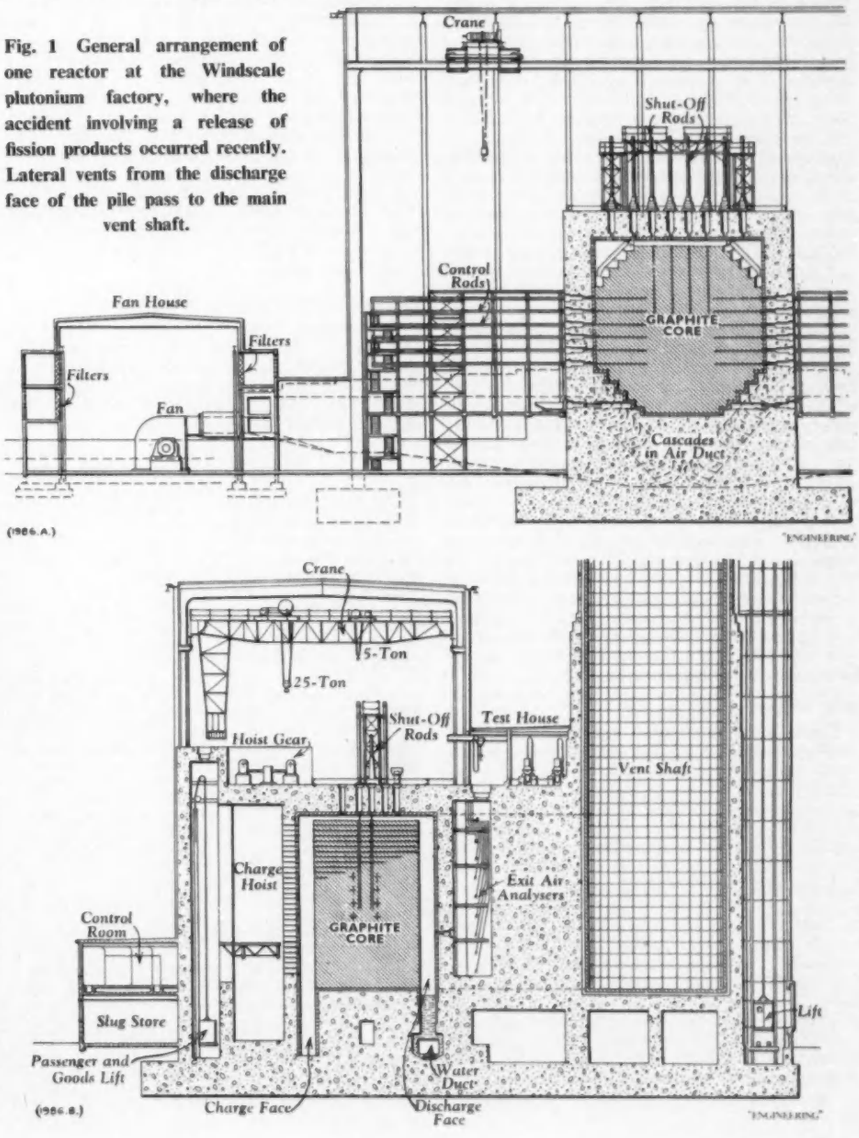


Fig. 1 General arrangement of one reactor at the Windscale plutonium factory, where the accident involving a release of fission products occurred recently. Lateral vents from the discharge face of the pile pass to the main vent shaft.

Continuing Atomic Review

in the Windscale No. 1 Pile in September, 1952, whilst the pile was shut down. This led to a rise of temperature of the graphite but the rise was not dangerous and there were no harmful effects. As a result of a study of this incident, a procedure was instituted for controlling release of Wigner energy; and eight such releases had been carried out by the end of 1956 in Pile No. 1. The general procedure was to shut down the pile, arrange the appropriate instrumentation and then cause the pile to diverge with no coolant airflow, thus raising the uranium and graphite temperatures and so starting the Wigner release in the graphite. The release is then self-sustaining. It has always been found difficult to release energy in all the graphite of the pile. Consequently, on three previous occasions, it was found necessary to apply a second nuclear heating, some time after the first nuclear heating, when it was seen from the behaviour of the thermocouples in the graphite that the release of Wigner energy was coming to a halt before all the graphite had been annealed.

Events Leading to the Accident

The pile was first made divergent for the Wigner release at 7.25 p.m. on October 7, and the nuclear heating was stopped early the following morning. Some hours later, it appeared to the operators then in charge of the Wigner release operation that the graphite temperatures were dropping rather than rising, and it was therefore decided to apply further nuclear heating. The committee of inquiry report on the basis of temperature records that although some of the graphite temperatures were falling and there were some in which no Wigner release was apparent, a substantial number of graphite thermocouple readings showed steady increases. However, acting on the observations which he had made, the physicist in charge decided to boost the release with a second nuclear heating. He had no Pile Operating Manual, with special sections on Wigner release, to help him, nor had he had the benefit of sufficient detailed instructions.

The pile diverged for the second nuclear heating at 11.5 p.m. on October 8. The uranium thermocouples showed a temperature increase lasting for about 15 minutes after the pile diverged. The committee studied the temperature-time records and decided that the maximum rate of rise of temperature for a few minutes was several times greater than that which is permitted in normal operations. However, the maximum uranium temperature recorded did not exceed the maximum normal operating temperature. The rapid rate of rise of the uranium temperatures was seen and the control rods were run in to reduce the pile power and thus allow the uranium fuel to cool somewhat. However, in the opinion of the committee, the damage leading to the accident had probably been done. One or more of the uranium cartridges in the lower front part of the pile had failed.

Instrumentation Faults

There were two separate and distinct faults of instrumentation affecting the second nuclear heating. First, the uranium thermocouples were situated at the region of highest uranium temperatures during normal operations and were not at the position of maximum uranium temperatures during Wigner release. Because of this the pile operator was unaware that the uranium fuel in the middle front regions of the pile was probably hotter than was indicated by the readings he was taking, and the rate of rise of temperature was certainly greater than he was observing. A second deficiency of instrumentation was that the pile power meter, while correct for normal operations, read low in the situation prevailing. The feel of the pile was different and the second nuclear heating was applied too quickly. The scanning gear for detecting burst cartridges also proved to be immovable in spite of maintenance work carried out on it on October 9.

Fire in 150 Channels

The picture that the committee pieced together revealed that, as a result of the second nuclear heating, graphite temperatures gradually rose through October 9. This led to the oxidation of the uranium which had been exposed by the overheating. The exposed uranium smouldered throughout the course of the day and gradually led to the failure of other cartridges and their combustion, and to the combustion of graphite. By the evening of Thursday, October 10, the fire had spread and was affecting about 150 channels in a region of rectangular cross-section.

Measures Taken

Late on October 9 and early on October 10 cooling was applied first by natural draught using the chimney and then using the fan dampers for successive periods ranging from 10 minutes to half an hour. (The fan dampers are comparatively small units, as distinct from the shutdown fans, which were only used later as a preliminary to moving the scanner or to blowing the pile cool, or later still to maintain tolerable working conditions during attempts to discharge the burning elements. The extensive use of the main fans might have led to wholesale dispersal of fission products.) All graphite temperatures fell under the action of the fan dampers except the highest, the rise of which was merely arrested. Subsequently the scanning gear was found to be out of order, but another instrument revealed a considerable burst. A charge plug was removed to inspect the channel showing the highest temperatures, and the uranium cartridges were seen to be at red heat. An attempt to discharge the affected channels, which are of course horizontal at Windscale, was frustrated by the jamming of distorted cartridges, but adjacent channels were cleared to make a fire break. Cooling by carbon dioxide sent in cylinders from Calder Hall proved ineffective. Early on the morning of October 11 the decision was taken to use water which was poured for over 24 hours. By the afternoon of October 12 the pile was cold.

Safety of Gas-Cooled Power Reactors

As pointed out in our Plain Words of October 18, the Calder Hall reactors and the nuclear power stations under construction in this country are not prone to similar misadventures, being fundamentally different in design from the Windscale piles.

Wigner Release.—The minimum temperature of the graphite at Calder Hall in normal operations is higher than the corresponding temperature at Windscale. The minimum operating temperature of the graphite in the first stations now under construction for the electricity authorities will be higher still. For this reason some annealing of the graphite will be going on continuously, and the storage of Wigner energy in the graphite will proceed at a much slower rate. All the evidence accumulated up to the present time indicates that these reactors will be able to operate for about five years before a Wigner release is required. This is being continuously checked by monitoring of the graphite in Calder Hall and by accelerated tests of graphite in the DIDO research reactor. When a Wigner release becomes necessary, it will not present any hazard because it can be conducted under fully controlled conditions, as indicated in the following points.

Uranium Combustion Temperature.—Whereas the Windscale piles are cooled by air the Calder Hall type reactors are cooled by carbon dioxide which does not react with uranium until appreciably higher temperatures than those at which the air reaction starts. In still air uranium oxidises, and the reaction is self-heating at 350 deg. C.; the corresponding temperature with carbon dioxide is 650 to 700 deg. C.

Choice of Coolant.—In the Windscale piles the air coolant is discharged into the atmosphere through a high stack. In the Calder Hall reactors the carbon dioxide coolant circulates in a closed circuit. The use of carbon dioxide as a coolant in a closed system makes it possible to keep the temperature generated by a Wigner release under close control by the use of the main cooling fans.

Fixed Monitoring Equipment.—The scanning gear in the Windscale piles is of the moving type and is designed to move upwards and downwards across the pile discharge face. At the high temperature experienced during the Windscale accident this gear jammed. The detection equipment at Calder Hall and in the electricity authorities' stations is fixed and provides a method of monitoring each fuel element channel without movement. Continuous monitoring, therefore, of the integrity of the fuel sheath will be carried out while Wigner releases are in progress, thus providing continuous information about the condition of the fuel elements. This will enable immediate remedial action to be taken to deal with any damaged fuel element.

Fuel Cartridges.—The fuel cartridges at Calder Hall are of much improved design and experience has proved that their failure rate is much lower than the failure rate of the Windscale fuel elements; the rate of attack by carbon dioxide has also been shown to be very slow. The fuel cartridges for the electricity authorities' reactors will incorporate these and further improvements.

Control System.—The instrumentation and control system for regulating the rate of pile power change in the Calder Hall and electricity authorities' reactors is much improved over those in the Windscale reactors.

Inert Gas Safeguard.—If tests should show any new factors in the storage of Wigner energy, there is ample time to introduce additional safeguards, for example, by filling the reactor circuit with an inert gas during the Wigner releases.

Design of Graphite Moderators

Three United Kingdom Atomic Energy Authority patents dealing with the design of graphite moderators have recently been published. The first is concerned with an elementary arrangement of graphite blocks devised to allow for Wigner growth; the second two describe refinements taking account of certain other factors in core design. The patents are as follows. Patent No. 785,876 (E. L. Ashley, J. W. Ashley, H. W. Bowker, R. H. Hall and J. W. Kendall) proposes an arrangement of graphite blocks designed to be dimensionally stable in an intense neutron field; Patent No. 784,291 (E. Long and J. W. Ashley) suggests modifications to prevent losses of neutrons through streaming; and Patent No. 784,292 (E. Long and J. W. Ashley) similarly seeks to minimise coolant-gas leakage.

Multiple Functions of Moderator Structure

In the conventional graphite-moderated nuclear reactor the graphite moderator structure fulfils multiple functions. In the first place it serves

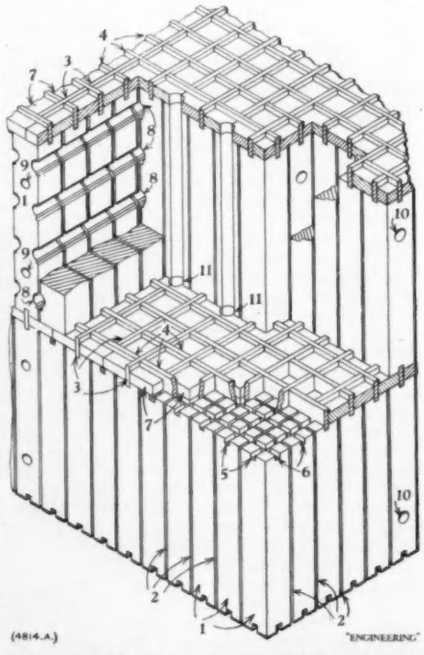


Fig. 2. Elementary design of graphite moderator structure to give dimensional stability irrespective of Wigner growth under neutron irradiation.

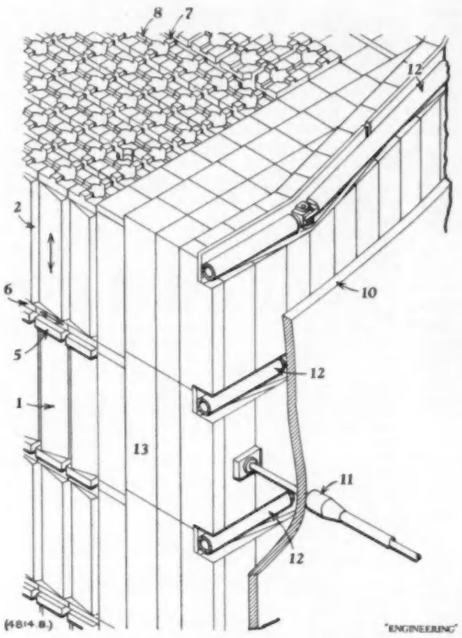


Fig. 3 Second design of graphite moderator structure to give dimensional stability. The design also serves to minimise neutron streaming and coolant losses.

to moderate neutron energies down to thermal levels whereby a chain reaction can be maintained with natural or only slightly enriched uranium. In the second place it serves to locate the fissile fuel elements on a suitably spaced lattice, and thirdly it serves to define channels for coolant flow over the elements. For these last two functions the moderator must be physically stable and contain a minimum of leakage paths for the coolant, such paths representing wasted pumping power and temperature dilution of the coolant gas emerging from the reactor. Another function served by the moderator is to provide channels to accommodate control rods, irradiation facilities, measuring gear and other items.

Dimensional Instability

It is customary that the graphite moderator structure is made from an assembly of graphite blocks and certain problems are met in such an assembly. These problems arise primarily from the necessity of maintaining physical stability in consideration of various factors.

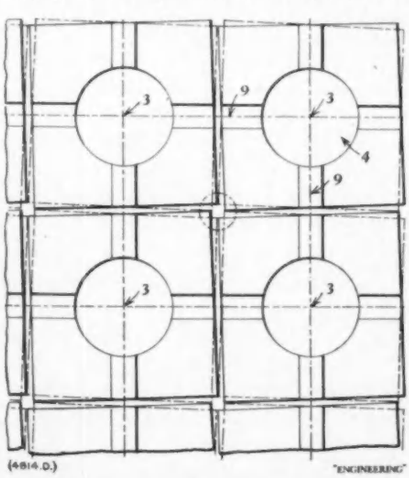


Fig. 4 Axial displacement of main graphite blocks relative to co-ordinate axes, showing central cooling channels and limits of streaming.

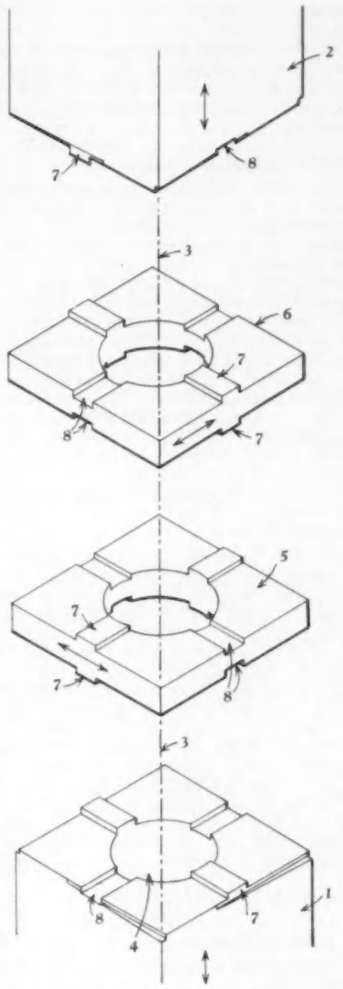


Fig. 5 Method of locating successive layers of moderator blocks using intermediate tiles, which butt together in strings across the reactor giving a fixed horizontal lattice.

The most prominent of these is Wigner growth. Under the large and non-uniform neutron flux resulting from the nuclear reaction the graphite mass tends to become distorted, and this distortion may set a limit to power load since the shape of the mass and of the channels in it must be kept within operating limits. Other factors are those of thermal expansion and the forces (when gas cooling is used) across the graphite structure tending to displace the structure.

Wigner Growth

Wigner growth is the physical expansion or change of shape of a material exposed to a neutron flux. In massive structures of graphite in which the Wigner effect is pronounced, the establishment of an intense neutron flux leads to swelling and expansion which introduce design difficulties in the erection and utilisation of the structure. A characteristic of Wigner growth in graphite is that it tends to differ in different directions through the material. However, blocks of graphite may be shaped with respect to the grain or texture so that the longitudinal growth in a uniform neutron field is the same for all blocks. When graphite is produced by extrusion or otherwise to have a pronounced grain, it is found that the Wigner growth is transverse to the grain, the growth along the grain being relatively small. The growth along the grain after prolonged exposure is in fact less than the thermal expansion experienced in bringing a pile up to its stable operating temperature and may be negative. The graphite thus exhibits an apparently two-dimensional Wigner growth. The length dimension of the block can be chosen to coincide with the direction of minimum Wigner growth.

Fixing Overall Dimensions

In one aspect of the first proposal (Patent No. 785,876), strings of graphite blocks having minimum Wigner growth properties in their longitudinal directions, stretch respectively through the width, breadth and height of the structure and determine its overall dimensions. Each string locates along its own length the neighbouring strings transverse to it, so that changes in the width and thickness of the individual strings have little or no effect on the overall dimensions. Thus although the material is anisotropic in its Wigner growth, the structure has a linear expansion which is independent of direction. It expands uniformly in a uniform field and its volume expansion in a given field is determinable. The spaces in the framework or skeleton so formed are filled with packing blocks with clearances that permit their free growth. Alternatively the members of the skeleton or framework may be closely spaced, that is with clearances between them only sufficient to permit the lateral Wigner growth, so that a substantially solid mass is formed by the structural members themselves.

Stable Moderator Structure

One form of the proposal may be described in detail with reference to Fig. 2. Graphite blocks (1) are arranged in horizontal layers one upon another with the graphite grain vertical so that the Wigner expansion is horizontal. Spaces (2) for taking up the expansion are left between the blocks of each layer, and horizontal ties (3, 4), in the form of graphite strips cut along the grain so that Wigner growth is in the transverse direction, are arranged to bridge the spaces. The blocks are preferably rectangular and of length along the grain equal to several times the width dimension; they are stood on end and the graphite strips extend between the layers in grooves (5, 6) cut in the end faces of the blocks. The grooves are sufficiently deep to permit vertical expansion of the strips, between which are inserted flat rectangular cross-grained packing blocks (7). The ties form a rigid horizontal locating lattice for the main units. All items must be machined to close tolerances, and holes cut for cooling channels (8), irradiation facilities (9), control rods (10), shut-off rods (11) and fuel channels (12).

The structure assembled in the way described exhibits negligible change in overall dimensions due to Wigner growth. The overall height is the sum of a number of block lengths and packing block thicknesses, all of which are in the direction of the graphite grain and so of small growth. Each of the blocks (1) is held to a fixed position in the horizontal plane by the ties (6, 7) and is free to expand laterally. The thickness of the spacings between the blocks is chosen to provide ample room for block expansion at the local neutron flux densities to be developed. At flux densities of the order developed in a plutonium-producing pile having aluminium-sheathed uranium rods as fuel, cooled by air pumped through at one or two atmospheres mean pressure, a spacing between the blocks of the order of $\frac{1}{4}$ in. is appropriate in the central regions of the structure; the spacing between the outer blocks and particularly between the blocks of the bottom and top layers may be less, for example, of the order of $\frac{1}{16}$ in.

Neutron Losses

In the course of this moderation process there is an inevitable loss of some neutrons. This loss may be regarded, in effect, as a loss or waste of fissile fuel and the cost of making good this waste is substantial. Design efforts are therefore directed to minimising neutron losses in and from the reactor core. Losses occur due to

escape of neutrons from the core and by the absorption of the neutrons into the materials forming the core and the coolant in the core. In a conventional graphite moderator structure made as an assembly of graphite bricks spaced to allow for Wigner growth, unimpeded paths through the reactor core exist in the vertical and horizontal directions along which neutron streaming takes place with a loss of neutrons.

Limitation of Neutron Streaming

In a proposed design (Patent No. 784,291) the graphite moderator structure for a nuclear reactor comprises an assembly of similarly orientated prismatic graphite blocks arranged on spaced longitudinal axes lying in common planes wherein the planes of the walls of the blocks are placed so as to be twisted relative to the planes of those axes, so that the unimpeded direct paths in directions wholly across the walls of the blocks are limited to the width of the blocks plus spacing between the blocks.

Inclined Orientation of Moderator Blocks

As can be seen from Fig. 3, the main prismatic blocks (1 and 2) are slightly displaced about their axes (3) in opposed senses. The double arrows in all cases indicate the directions of minimum Wigner growth. Fig. 4 is a plan view showing the displacement more clearly. The axes (3) are arranged on a rectangular lattice, and are the centre-lines of cooling channels (4). The horizontal location of the blocks is effected by means of tiles having minimum Wigner growth along their edges, as indicated by the arrows in Fig. 5. One set of tiles (5) butt together and locate in a string across the reactor, while another set (6) locate in a direction at right angles to the first. Keys (7) and keyways (8) are cut in the tiles parallel to the co-ordinate axes (9), while corresponding keys and keyways in the faces of the blocks are at 2 deg. to these axes. The coolant-channel holes in the tiles are slightly larger than in the main blocks, and the keyways are cut to allow the necessary Wigner expansion of the blocks, which are spaced accordingly. Vertical growth is negligible, since blocks and tiles are designed to give minimum growth in that direction.

Minimising Coolant Losses

The same design (Patent No. 784,292) is arranged so as to give minimum coolant leakage. By using coolant channels which are bores in solid blocks leakage between channels is reduced; and the close-fitting end faces of the graphite blocks and tiles only allow inter-channel leakage along the clearance between the keys and keyways.

Overall Moderator Design

The design, together with dimensions, tolerances and other parameters, is given in the specifications in considerable detail. The total voidage, for example, is stated to be 3 per cent. Fig. 3 shows the pressure vessel (10), supporting a Wigner growth measuring probe (11). Tension bands (12) are provided round the structure at each level around the 24-sided structure. The height of the structure is 27 ft., and it is designed for inlet and outlet temperatures of 140 and 350 deg. C. There are no spaces between the reflector graphite blocks (13), and no provision for tiles, since in the reflector Wigner growth is negligible.

General Notes

Reactor Accidents

All five countries with major nuclear programmes have now experienced reactor accidents; Britain has been the last to suffer in this way. Canada's NRX reactor was seriously damaged by a power surge in December, 1952; an experimental breeder reactor (EBR-1) suffered a similar mishap in the United States in November, 1955; a minor incident, when a fuel-can burst releasing fission products into the atmosphere occurred at Saclay in France in June, 1956; and in February, 1957, the American experimental reactor Godiva disintegrated during a power surge. Other accidents are understood to have occurred in the United States and U.S.S.R., but details are not available. The deliberately induced run away of BORAX-1 can hardly be classified as an accident.

Fusion and the B.N.E.C.

An article on thermonuclear fusion by Dr. A. A. Ware appears on page 610, and is followed by notes concerning the British Nuclear Energy Conference.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
"Special Effect Lighting," by W. R. Stevens. Magnet House, Kingsway, W.C.2. Tues., Nov. 19, 6.30 p.m.*

British Computer Society

LONDON
"Applications of a Computer to the Work of the Norwich Corporation and Plans for Future Use," by A. J. Barnard. Conference Room, County Hall, S.E.1. Mon., Nov. 18, 6.15 p.m.

British Institution of Radio Engineers

EDINBURGH
"V.H.F. Frequency-Modulated Transmission," by H. V. Sims. Scottish Section. Department of Natural Philosophy, The University, Edinburgh. Fri., Nov. 22, 7 p.m.
GLASGOW
"V.H.F. Frequency-Modulated Transmission," by H. V. Sims. Scottish Section. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Thurs., Nov. 21, 7 p.m.

Chemical Society

LONDON
Various short papers. Thurs., Nov. 21, 7.30 p.m.
BRISTOL
"Silicones: an Introduction to Their Chemistry and Applications," by Dr. G. G. Freeman. Bristol Branch. Chemistry Department, The University, Bristol. Thurs., Nov. 21, 5.15 p.m.
LEICESTER
"Gas Chromatography," by C. S. G. Phillips. Nottingham and Leicester Branch. The University, Leicester. Mon., Nov. 18, 4.30 p.m.
SHEFFIELD
"Nuclear Magnetic Resonance," by Dr. R. E. Richards. Sheffield Branch. Chemistry Lecture Theatre, The University, Sheffield. Thurs., Nov. 21, 7.30 p.m.

Diesel Engineers and Users Association

LONDON
"Fuel Injection Equipment," by G. R. Green. Caxton Hall, off Victoria-street, S.W.1. Thurs., Nov. 21, 2.30 p.m.

Illuminating Engineering Society

LONDON
"Modern Planning Trends in Office Buildings and Factories," by John Bickerdike. Royal Institute of British Architects, Portland-place, W.1. Thurs., Nov. 21, 6 p.m.

Incorporated Plant Engineers

ASHFORD
"Clutches," by E. Whiteley. Kent Branch. County Hotel, High-street, Ashford. Wed., Nov. 20, 7 p.m.
BLACKBURN
"Heat Pumps," by A. W. Bates. Blackburn Branch. Golden Lion Hotel, Blackburn. Thurs., Nov. 21, 7.30 p.m.

Institute of Fuel

BIRMINGHAM
Various short papers. Midland Section. Imperial Hotel, Temple-street, Birmingham. Wed., Nov. 20, 6.15 p.m.
EDINBURGH
Various short papers. Scottish Section. North British Hotel, Edinburgh. Thurs., Nov. 21, 7 p.m.
LEEDS
"The Cost of Steam," by K. C. Wales. Yorkshire Section. Hotel Metropole, Leeds. Wed., Nov. 20, 7 p.m.

Institute of Marine Engineers

BIRKENHEAD
"Engine Room Equipment," by J. N. Cairns. Merseyside and North Western Section. Birkenhead Technical College, Birkenhead. Wed., Nov. 20, 7.15 p.m.
BOLTON
"Engine Room Equipment," by J. N. Cairns. Merseyside and North Western Section. Bolton Technical College, Bolton. Fri., Nov. 22, 3 p.m.
KINGSTON-UPON-HULL
"Marine Lubrication," by G. H. Clark. Kingston-upon-Hull and East Midlands Section. Royal Station Hotel, Kingston-upon-Hull. Thurs., Nov. 21, 7.30 p.m.
SWANSEA
"Modern Marine Steam Turbines," by J. H. Gooch. South Wales Section. Swansea Technical College, Mount Pleasant, Swansea. Fri., Nov. 22, 2.15 p.m.

Institute of Metals

BIRMINGHAM
"Metallurgical Thermodynamics," by Dr. J. N. Pratt. Birmingham Local Section. Birmingham Exchange and Engineering Centre, Stephenson-place, Birmingham. Thurs., Nov. 21, 6.30 p.m.

Institute of Physics

GLASGOW
"Nuclear Power Production," by D. C. G. Smith. Scottish Branch. Department of Natural Philosophy, The University, Glasgow. Tues., Nov. 19, 7.15 p.m.
SHRIVENHAM
"Field Emission of Electrons," by Professor F. A. Vick. South Western Branch. Royal Military College of Science, Shrivenham. Fri., Nov. 22, 7 p.m.

Institution of Chemical Engineers

MANCHESTER
Two papers on "Pressure Vessels," one by R. W. Lakin. North Western Branch. College of Science and Technology, Manchester. Tues., Nov. 19, 7 p.m.

Institution of Civil Engineers

LONDON
"Langstone Bridge, Hampshire," by J. W. Melrose and W. A. Eyre. Tues., Nov. 19, 5.30 p.m.*
LIVERPOOL
Address by the chairman. North Western Association. Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool. Wed., Nov. 20, 6.30 p.m.

Institution of Electrical Engineers

LONDON
Discussion on "The Measurement of the Dynamic Characteristics of Electrical Machines." Joint Meeting of Measurement and Utilization Sections. Tues., Nov. 19, 5.30 p.m.*
"Earthing of Low and Medium-Voltage Distribution Systems and Equipment," by F. Mather. Supply Section. Wed., Nov. 20, 5.30 p.m.*
Discussion on "High-Voltage Experiments," opened by Professor E. Bradshaw. Education Discussion Circle. Thurs., Nov. 21, 6 p.m.*
Discussion on "Radio Observations on the Russian Satellite." Radio and Telecommunication Section. Fri., Nov. 22, 2.30 and 5.30 p.m. (Tea at 4.30 p.m.)
LEEDS
"Some Aspects of Heat-Pump Operation in Great Britain, with Particular Reference to the Shinfield Installation," by Miriam V. Griffith. North Midland Centre. Offices of the Yorkshire Electricity Division, 1 Whitehall-road, Leeds. Tues., Nov. 19, 6.30 p.m.
LIVERPOOL
"Half-Wave Magnetic Amplifiers," by G. M. Ettinger. Mersey and North Wales Centre. Royal Institute, Colquitt-street, Liverpool. Mon., Nov. 18, 6.30 p.m.
LOUGHBOROUGH
"Design for Production," by H. T. Price. East Midland Centre. Loughborough College, Loughborough. Tues., Nov. 19, 6.30 p.m.*

Institution of Electronics

BELFAST
"A Low-Frequency Decade Oscillator," by A. W. S. Gilham. Union Hotel, Donegall-square South, Belfast. Tues., Nov. 19, 7.30 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

* An asterisk is placed where it is understood that tea is available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 3927.)
British Computer Society, 29 Bury-street, St. James's, London, S.W.1.
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Diesel Engineers and Users Association, 19 Old Queen-street, London, S.W.1. (TRAfalgar 5597.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 12 The Parade, Solihull, Warwickshire. (Solihull 1111.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Marine Engineers, Memorial Building, 76 Mark-lane, London, E.C.3. (ROYal 8493.)
Institute of Metals, 17 Belgrave-square, London, S.W.1. (BELgravia 3291.)
Institute of Physics, 47 Belgrave-square, London, S.W.1. (BELgravia 6111.)
Institution of Chemical Engineers, 16 Belgrave-square, London, S.W.1. (BELgravia 3647.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Electronics, 78 Shaw-road, Thornham, Rochdale, Lancs. (Oldham Main 6661.)
Institution of Engineering Designers, 38 Portland-place, London, W.1. (LANgham 8847.)
Institution of Engineers-in-Charge, 100 Earlsfield-road, London, S.W.18. (BATtersea 1394.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)
Institution of Locomotive Engineers, 28 Victoria-street, London, S.W.1. (ABBey 6672.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Mining and Metallurgy, 44 Portland-place, London, W.1. (LANgham 3802.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1. (SLOane 7128.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Royal Institution, 21 Albemarle-street, London, W.1. (HYDe Park 0669.)
Royal Meteorological Society, 49 Cromwell-road, South Kensington, London, S.W.7. (KENsington 0730.)
Royal Society, Burlington House, Piccadilly, London, W.1. (REGent 3335.)
Royal Society of Arts, John Adam-street, Adelphi, London, W.C.2. (TRAfalgar 2366.)
Royal Statistical Society, 21 Bentinck-street, London, W.1. (WELbeck 7638.)
Scientific Film Association, 164 Shaftesbury-avenue, London, W.C.2. (TEMple Bar 4694.)
Society of Chemical Industry, 14 Belgrave-square, London, S.W.1. (BELgravia 3681.)
South Wales Institute of Engineers, Park-place, Cardiff. (Cardiff 23297.)

Institution of Engineering Designers

LONDON
Conference on "Training of Engineering Designers and the Improvement of Careers in the Drawing and Design Office." Sat., Nov. 23, 10.30 a.m. (Tickets required.)

Institution of Engineers-in-Charge

LONDON
"Special Effect Lighting," by W. R. Stevens. Joint Meeting with the A.S.E.E. Magnet House, Kingsway, W.C.2. Tues., Nov. 19. 6.30 p.m.*

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
"Recent Developments in Cycloidal Propellers," by Captain E. C. Goldsworthy and W. Betts Brown. Tues., Nov. 19, 6.30 p.m.

Institution of Locomotive Engineers

LONDON
"Vibrational Aspects of Bogie Design," by J. L. Koffman. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Wed., Nov. 20, 5.30 p.m.*

Institution of Mechanical Engineers

LONDON
Discussion on "Instrumentation for the Measurement of Fluid Pressure." Hydraulics Group. Thurs., Nov. 21, 6.45 p.m.*
Technical Film Show. Fri., Nov. 22, 6.45 p.m.* (By ticket).
BRISTOL
Thomas Hawksley Lecture: "Vibration—A Survey of Industrial Applications," by Professor J. P. den Hartog. Western Branch. Engineering Laboratories, University-walk, Bristol. Tues., Nov. 19, 7 p.m.
CAMBRIDGE
Thomas Hawksley Lecture: "Vibration—A Survey of Industrial Applications," by Professor J. P. den Hartog. Eastern Branch. Engineering Laboratory, University of Cambridge, Trumpington-street, Cambridge. Mon., Nov. 18, 7.30 p.m.
DERBY
Chairman's Address on "Experiments with Internal-Combustion Engines," by R. C. Cross. Derby A.D. Centre. Midland Hotel, Derby. Mon., Nov. 18, 7.15 p.m.
GLASGOW
"Servicing the Modern Vehicle," by A. D. Reid. Scottish A.D. Centre. 39 Elmbank-crescent, Glasgow, C.2. Mon., Nov. 18, 7.30 p.m.

Institution of Mining and Metallurgy

LONDON
"Pulp Density Measurement with Ultrasonics," by J. K. Almond and A. R. Burkin; and "Changes in Copper Solubility During Flotation of Malachite," part 2, by E. J. Pryor and G. M. Lowe. Geological Society, Burlington House, Piccadilly, W.1. Thurs., Nov. 21, 5 p.m.*

Institution of Production Engineers

BELFAST
"Hydraulic Operation of Machine Tools," by H. C. Town. Northern Ireland Section. Kensington Hotel, Belfast. Thurs., Nov. 21, 7.30 p.m.
BIRMINGHAM
"Technical Education in the U.S.A.," by T. B. Worth. Birmingham Section. James Watt Memorial Institute, Birmingham. Wed., Nov. 20, 7 p.m.
CARDIFF
"Control of Dust," by W. B. Lawrie. Cardiff Section. South Wales Institute of Engineers, Park-place, Cardiff. Fri., Nov. 22, 7 p.m.
COVENTRY
Discussion on "Modern Gear Hobbing Practice." Coventry Section. Craven Arms, High-street, Coventry. Mon., Nov. 18, 7.15 p.m.
GLASGOW
"Manufacture of Small Metal Pressings," by H. W. Townsend. Glasgow Section. 39 Elmbank-crescent, Glasgow. Thurs., Nov. 21, 7.30 p.m.

Institution of Structural Engineers

MIDDLESBROUGH
Joint Management Meeting. Lecture by Peter G. Masefield. Northern Counties Branch. Cleveland Scientific and Technical Institution, Middlesbrough. Wed., Nov. 20, 6.30 p.m.*

Junior Institution of Engineers

LONDON
"Blowing of Blast Furnaces," by W. K. V. Gale. Fri., Nov. 22, 7.30 p.m.*

Royal Aeronautical Society

LONDON
"The Supersonic Wind Tunnel," by Dr. W. F. Hilton. Tues., Nov. 19, 7 p.m.
"Guided Weapons and Aircraft: Some Differences in Design and Development," by J. E. Serby. Inaugural Lecture of Guided Flight Section. Royal Institution, Albemarle-street, W.1. Thurs., Nov. 21, 6 p.m.*

Royal Institution

LONDON
"Physics and the Astronomical Universe," by Professor W. H. McCrea. Fri., Nov. 22, 9 p.m.

Royal Meteorological Society

LONDON
Various short papers. Wed., Nov. 20, 5 p.m.*

Royal Society

LONDON
Annual Report of Council. Various short papers. Thurs., Nov. 21, 4.30 p.m.*

Royal Society of Arts

LONDON
"Exploring the Deep Ocean Floor," by A. S. Laughton. Wed., Nov. 20, 2.30 p.m.

Royal Statistical Society

LONDON
Presidential Address on "Recent Developments in Economic Statistics," by Sir Harry Campion. London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. Wed., Nov. 20, 5.15 p.m.*

Scientific Film Association

LONDON
"Documentary and Scientific Films in the U.S.S.R.," by Donald Alexander. Mezzanine Cinema, Shell-Mex House, Strand, W.C.2. Thurs., Nov. 21, 6.30 p.m.

Society of Chemical Industry

LONDON
"Protection of Magnesium Alloys," by Dr. W. F. Higgins. Wed., Nov. 20, 6.30 p.m.

South Wales Institute of Engineers

CARDIFF
"Hydraulic Drive—The Modern Transmission," by R. H. Fett. Thurs., Nov. 21, 6 p.m.

In Parliament

SCIENCE INSPIRED BY HOPE

With the opening of a new session on November 5, the third session of the present Parliament, interest in the affairs of the two Houses during the past week has naturally been centred mainly upon the Queen's Speech and the debates arising thereon.

Such Speeches are largely an indication of the work which the Government of the day propose to undertake during the ensuring months and the most outstanding of the remarks made by Her Majesty on this occasion was her statement that the Government are mindful that, at this momentous time, the advance of science into the unknown should be inspired by the hopes, and not retarded by the fears, of mankind.

The Government, said Her Majesty, were resolved to take all necessary steps to maintain the value of Britain's money, to preserve the economic basis of full employment by restraining inflation, to strengthen the country's balance of payments and to fortify her reserves, upon which the strength of sterling, and hence, the strength of the sterling area as a whole, depended. A Bill would be introduced to revise and codify existing legislation relating to import duties. A measure would also be placed before Parliament to establish a Conservancy Authority for Milford Haven, to regulate the increased maritime traffic which should result from the projected development of that important harbour.

The Government welcomed the recommendation, made by the recent meeting of Commonwealth Finance Ministers in Canada, that a Commonwealth Trade and Economic Conference should be held next year. They considered that such a conference would provide a valuable opportunity to reinforce still further the economic ties between members of the Commonwealth. The Government also welcomed the declaration by the Council of the Organisation for European Economic Co-operation of their determination to promote the establishment of a European Free Trade Area.

SOLVING THE WAGES PROBLEM

In the Commons debate on the Speech, Mr. Hugh Gaitskell (Labour) expressed the view that the most important part of the Government's proposals regarding local government was the replacement of the percentage grant by the block grant. Overwhelmingly, the most important service to be affected would be education. The parties most concerned with that measure, the education committees, had described it, through their associations, as spelling disaster for the education system.

Another point referred to by Mr. Gaitskell was the attitude of the Government to wage and salary claims by their own employees and by the employees of the nationalised industries. Would the Government reject all claims regardless of merit or, on the other hand, were they ready to agree that arbitration boards, whether in the public or the private section of industry, might deal with claims on their merits? This aspect was of much importance as it could not be said that all wage claims had exactly the same merits. Solving the wages problems could only be achieved by treating leaders of industry on both sides as adults. It was not too late for the Government to change their course and he hoped that, guided by wiser counsels, they would do so.

NO ROOM FOR INFLATION

Mr. Harold Macmillan, the Prime Minister, referred to the growing burden upon Ministers, to which consideration had been given by Lord Attlee and four other Privy Councillors. No new or precise rules were needed. While retaining full responsibility, Ministers in charge of Departments could take advantage of the help given to them by their junior colleagues. If these junior Ministers were to be regarded as deputy Ministers, they must be recognised as having that authority. He hoped a convention would grow up to accept them as spokesmen for their Departments.

The Government was resolved that Britain's membership of a European association must be wholly compatible with the full maintenance of her special relationship with Commonwealth countries. The Government had been, and would continue to be, in close touch with their Governments all through. They would also keep in consultation with both sides of industry and rely much on their advice as the scheme unfolded. Negotiations might well be prolonged.

In regard to the wages situation, Mr. Macmillan said that the British were far too sensible a people to support an attempt to make the present situation an occasion for dividing the country by industrial strife. Up to now, it was unemployment that had been feared rather than inflation. That was because Britain had had experience of high unemployment but never of a runaway inflation. But it was surely becoming increasingly clear that it was on the curbing of inflation and the stabilising of the pound that the full employment of the country must depend. The Government would stand by the arbitration system and would rely upon making the necessary financial adjustments. Wage increases must be earned within the particular sphere which wanted them or be met by corresponding savings in other parts of the national economy.

IMPROVING TRADE WITH CANADA

The Government have been greatly encouraged in their belief in the future prospects for Anglo-Canadian trade by the recent discussions which have taken place between the Prime Minister and Foreign Secretary and Canadian Ministers. The communiqué issued at the conclusion of these talks described a number of ways in which it is hoped to improve United Kingdom trade with that Dominion. In particular, the Government are looking forward to welcoming Mr. Gordon Churchill, the Canadian Minister of Trade and Commerce, on his visit to this country next month at the head of a high-level Canadian trade mission.

In giving this information to the House, Mr. J. K. Vaughan-Morgan, the Minister of State to the Board of Trade, said that, in conjunction with the High Commissioner for Canada and the Dollar Exports Council, the Government were arranging for the mission to make extensive visits to industrial centres and to inform themselves at first hand of the developments made by industry in the United Kingdom since the war.

WELSH TINPLATE INDUSTRY

The situation arising in South Wales from the closure of certain old-type tinplate works in the western part of the district was referred to by Mr. Herbert Gower (Conservative), who asked the Minister of Labour for a statement regarding alternative employment for the persons affected.

Ten hand tinplate works, Mr. Iain Macleod stated, were in process of closing or were expected to close. Although employment in the industry fell by just over 2,400 between January and the end of September this year, only 255 former tinplate workers were registered as wholly unemployed on October 14. On the same date, the total number of unemployed persons in the tinplate area of western South Wales was just over 4,400, or about 2·2 per cent. of the persons in work. The increase of 800 persons since the end of September was entirely due to a rise in the number of employees temporarily stopped. More than half of these persons were tinplate workers and many of them had been affected by short-time working at the modern cold reduction plants. The firms concerned had been able to offer alternative employment in the iron and steel industry to many of the workers affected by the closures. He was closely watching the position.

The Human Element

Supping with a Long Spoon

This week a conference has been held of all the organisations whose members are in the Health Service. Among those present were the B.M.A., the Royal College of Nursing and the Transport and General Workers' Union. Metaphors abound on such a situation. Is the lion at last lying down with the lamb? Is misery acquainting men with strange bedfellows? Choose which one you may, the coming together of these professional and union organisations is significant for the future.

The occasion of the meeting is to protest over the Minister of Health's veto on the 3 per cent pay increase for certain grades of administrative and technical staff. The professional bodies have to walk warily on these matters. Much as they may deplore the Government's attitude they must realise that their pre-occupation with the welfare of those with whom they work is balanced on the union side with what may be a golden political opportunity. The union would have won a useful point for its other coming struggles on pay if it could have ranged a body like the B.M.A. on its side during the first round of the struggle. Behind all this, too, are some basic issues about skill and professional status. Is it right, for instance, for the established professions to take up the cudgels for organised workers with an acquired skill which is not of a professional standard? In the process, do the skilled workers go up or do the professional ones come down?

Productivity among the Russians

A publication put out by the Labour Information Office of the United States Information Service called *Soviet Policies on Labour Productivity and Trade Unions* brings together an interesting collection of Russian extracts on how productivity is raised in Russia by forms of exploitation which are often imputed to the western world. Like all such propaganda material it falls slightly short of its target by publishing extracts out of context (an unavoidable but dangerous procedure) and by making a case which suffers from repetition through the selections. Material of this kind, however, could be usefully used in under-developed territories which are at present rather dizzily admiring the circling Sputniks.

When full allowance has been made for all the authoritarian methods employed, the Russians can still take advantage of one group of stimulants which the rest of the world is still trying to develop. These are the stimuli, the incentives of the group and the value of group loyalties. Many Russians can probably feel that they are secure, that they " belong " and that they are important to the combined result at the far end of the factory to a degree which the western democracies are now striving to stimulate. It is true that the Russian satellites are a rotating monument to the low standard of living in the Soviet as well as to its technical skill. Nevertheless, many Russians may think they have a just direct pride in their accomplishment.

P.O. Workers and Arbitration

An interesting complication arises on the question of wage increases with the latest moves on the pay proposals for post office technical workers. Following the recent investigations by the Civil Service Pay Research Unit, adjustments have been made in Civil Service technician's pay to keep it in line with the market rate paid outside Government service. The Government intends to go ahead with bringing these technical grades into line, thereby showing that its ideas about a general " wage freeze " are not inflexible.

Meanwhile, the union has objected to the latest offer made in the process of adjustment (there were certain increases last June) and has intimated that it will go to arbitration. If it does, this may well be the first arbitrational tribunal to sit since the Government expressed its views about the need for arbitrators to take seriously into account in their findings the state of the economy and the climate of public opinion.

So far as the Civil Service as a whole is concerned, the firmer line taken by the Government on wage increases could not have come at a worse time. The higher Civil Service did not have their salaries raised in June when the 5 per cent. increase was given for " economic " reasons. Is the Government going to be bound by its own precedents or by the recent decision on wage increases? Justice to certain grades of the Civil Service may yet sit uneasily on the " wage freeze " and the fact that they may be basically unconnected is small comfort to the Government.

B.I.M. at Bournemouth

At their annual conference at Bournemouth last week, the British Institute of Management introduced themselves in a new light. Their director, Mr. F. R. Livock, addressed a special meeting of delegates and gave them a brief review of the Institute's work. His statement was supported by an attractively presented four-page brochure containing a very brief summary of what the B.I.M. offer to both the collective and the individual member under the heading " The Value of B.I.M. to Management." The two inside pages contain a graphic representation, in colour, of the organisation and activities of the Institute including a staff organisation chart. On the back page are the names of the chief executives at headquarters and in the five regional offices.

Mr. Livock is an engineer who came to his present job from a large electrical engineering company. He has come to it obviously with a strong belief in the need for such an organisation and with first-hand knowledge of industry's needs. One had the feeling that he had swept away many cobwebs, including some very sticky ones. The B.I.M. slogan, " better management in Britain," is to be heard farther afield than ever before in the ten years of its life so far. The amalgamation with the Institute of Personnel Administration has provided a first class regional network and some very useful additional members. The removal of the head office from unsuitable and expensive premises in Hill-street, Mayfair, to Management House, Fetter-lane, has provided an opportunity for a thorough clean-up of the organisation and for economy. The impression Mr. Livock gave was one of resolve to get on with what he believed to be an immensely important job, with the backing of a live and intelligent team.

Sharing the Blame

Both parties were to blame in the de Havilland Aircraft dispute which led to a strike last September. The management attempted to impose a settlement of a holiday issue without negotiating with the unions concerned and the unions called a strike before they had exhausted the negotiating procedure. As so often happens in situations where communication between the shop-floor (in this case the drawing office were first involved) and the boardroom are imperfect an atmosphere lacking in mutual sympathy and understanding prevailed. The committee of inquiry who were appointed by the Ministry of Labour, under the chairmanship of Mr. C. W. Guilleband, consider that the companies and the unions should get together informally as quickly as possible.

The strike began among draughtsmen at de Havilland factories in Portsmouth and Christchurch in July, spread to members of the Association of Engineering and Shipbuilding Draughtsmen at de Havilland works throughout Britain in September and involved members of the Association of Supervisory Staffs, Executives and Technicians a week later. Some 3,000 draughtsmen and supervisors were involved in the strike.

The Committee say that the management were ill-advised in the manner in which they made and promulgated their decision to grant two extra days holiday to certain employees. They committed a definite breach of their agreement with A.E.S.D. and their action " damaged the industrial relations between the company and the union prior to the issue of strike notices." But the A.E.S.D. were quite unjustified in taking strike action before having exhausted all the stages laid down in the agreement. " However much they could plead provocation, they were bound by their own agreement and should not have broken it." A.S.S.E.T. called out their members " in violation of the whole spirit of the undertakings into which they had entered as a free and consenting party." In other words, all the fuss, bad temper and loss of output and wages were all rather unnecessary.

Vocation with Vacation

Since the International Association for the Exchange of Students for Technical Experience was formed in 1948, the number of exchanges has gone up steadily from 920 in 1948 to 5,934 in 1957. This year, the largest exporting countries have been Germany (easily the largest) followed by Austria and Great Britain. The largest importing countries were Germany (again easily the biggest) followed by Britain (easily in second place). There is therefore no doubt that the organisation has made most progress in Germany, with Britain a not very good second.

A new handbook called *Vacation Training* has been put out by the Imperial College of Science and Technology, dealing with the College's vacation work scheme and also with the British side of the international organisation's exchange work. On I.A.E.S.T.E.'s British side, the Imperial College has developed projects with 36 universities and colleges in 18 countries during the current year. It sent out 731 students and received 778. The biggest exchange was with Sweden, followed by Germany, France and the Netherlands.

Two Curves Cross

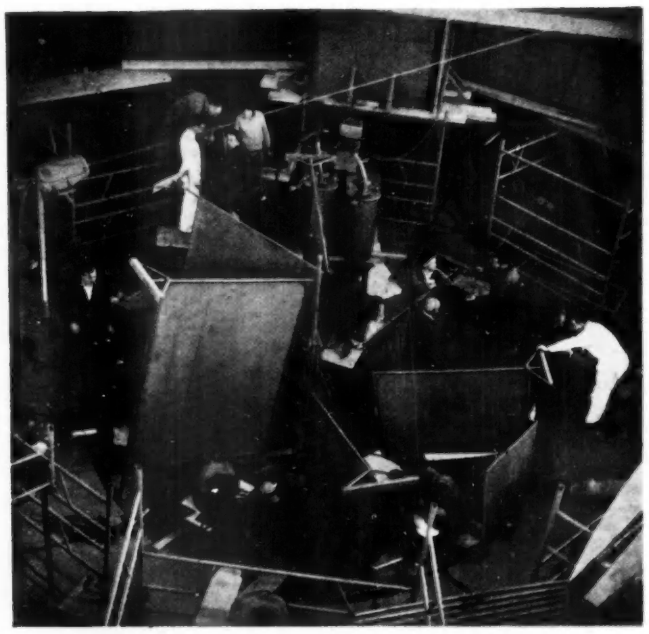
It is notoriously difficult to measure changes in inflationary pressure. Rough and ready devices have to be used and they are better than nothing. One guide to the trend of that pressure is the relation of the total figure of unemployed with the total number of unfilled vacancies. When vacancies exceed unemployed, pressure is positive; when unemployed exceed vacancies, pressure is negative. The two figures can be plotted over a period of time.

The graph of the two lines shows that they have just crossed. Vacancies have declined to 274,000. Unemployment in October stood at 275,000. Over the month, vacancies dropped by 9,000 and the unemployed rose by 8,000. The crossing of the curves is indicative of a change from inflation to something which, if it persists, can be called deflation.

Such indices of activity have to be used with care. They ignore regional differences, varying degrees of skill and experience in different industries. Thus a very bad spell of weather could put a large number of unskilled building workers out of work temporarily without affecting many skilled engineers. In contrast, a slump in shipbuilding would hit skilled men and certain localities without, by itself, seriously lowering the overall figures. Nevertheless, when these two curves cross each other (either way) an economic amber light flashes.

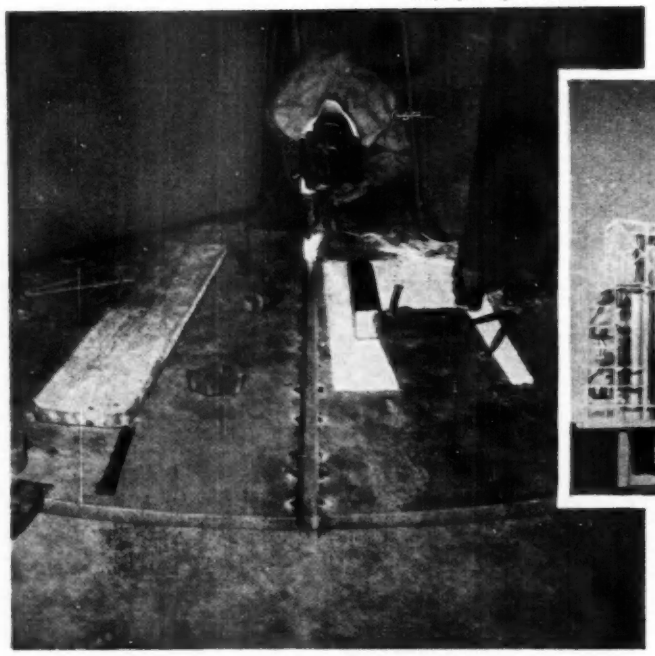
ENGINEERING

An Illustrated Weekly Journal



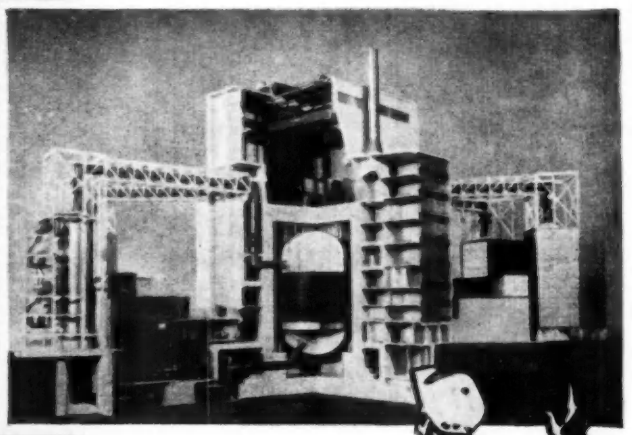
Welding begins inside the bowl of the reactor vessel. Six teams of John Thompson welders work outwards from the centre, welding the 3in. thick steel plates which have been assembled and are temporarily held in position by clamps. Further welding teams began working on the next ring of plates shortly after this photograph was taken. In the background, an X-ray unit stands ready inside the bowl for weld examination.

A welder works from the bottom centre of the reactor vessel, welding together the 3in. thick 'petal' plates which form the lower bowl. Accurate edge preparation of the plates has been achieved by a specially developed flame planing technique in John Thompson's works. The temperature of the weld area is maintained between welding runs by means of flame torches, one of which is seen ready to hand, in front of the welder.



Buttercups at Berkeley...

John Thompson's construction men — familiar in their yellow helmets on power station and industrial sites throughout Britain — are now at work on the Central Electricity Authority's first commercial nuclear power station being built by the A.E.I. — John Thompson Nuclear Energy Company at Berkeley, Gloucestershire. Crisply, the construction programme proceeds to a minutely planned schedule. The bottom dome portion of one of the huge 1,000 ton reactor vessels was transported in sections to the site where it is being welded together to grow simultaneously with the reactor building. The "Buttercups" are speedily getting on with this job in which they are building the reactor vessels, the thermal shielding, the sixteen large heat exchange towers, gas ducting and nuclear fuel loading machines.



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